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THE OHIO JOURNAL OF SCIENCE

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JANUARY, 1942

No. 1

THE JOURNAL CHANGES EDITORS AND MANAGERS

At a recent meeting of the Joint Administrative Board of the Ohio Journal of Science the resignation of the editor, Dr. Laurence H. Snyder, was accepted with regret. Dr. Snyder became Associate Editor of the Journal in 1932, and Editor-in-Chief in 1933. During his ten years with the Journal several customs have been inaugurated, among which are the reviewing of books, the coöperative publishing of symposia of the Society of the Sigma XI, and periodic exhibits before the Academy of Science of the detailed manner of printing and publishing the Journal.

The new Editor-in-Chief is Dr. Glenn W. Blaydes of the Department of Botany of the Ohio State University. Dr. Blaydes has been the Associate Editor for the past year, and is well acquainted with the problems and interests of the Journal.

Last spring Dr. Bernard S. Meyer resigned after ten years as Business Manager of the Journal, and his place was filled by Dr. John A. Miller of the Department of Zoölogy of the Ohio State University. The Ohio Academy of Science and the Ohio State University wish success to the new Editor and Business Manager at the start of their careers.

THE ADMINISTRATIVE BOARD.

SPECIES ISOLATION AND A PROGLACIAL LAKE IN SOUTHERN OHIO¹

JOHN N. WOLFE
Ohio State University

The diverse geographic affinities of the Ohio flora have long been recognized and a large number of investigators have contributed to our knowledge of them. From the viewpoint of floristics alone, the complexity of the history of the primary vegetation of the region is strikingly illustrated by the presence of numerous disjunct species characteristic of prairie, plains, hemlock-hardwood and boreal plant formations.

That the arrival of plants characteristic of northern formations was associated with the advance of continental ice sheets of the Pleistocene has long been accepted. The persistence of boreal relic species in bogs, coves, on cliff tops and sand dunes is a conspicuous feature of many habitats in the state. Likewise, a pre-historic event in the form of a post-Wisconsin dry period accounts for the occurrence of continuous migration routes through the previous deciduous forest and the ultimate arrival in Ohio of many western species. An impressive set of data supporting the existence of a long dry period has been published by Transeau (17). Moreover, the areas where conspicuous assemblages of prairie species were dominant at the time of settlement in the state have been mapped.

In his ecology lectures for 20 years and in a recent paper, Transeau (18) has recognized still another group of plants growing in Ohio that have definite affinities southward; but the time and route of their migration into this region is not so clear. Braun (1), Thompson (15), and Schaffner (11), of the more recent writers, have also recognized this element. Griggs (3) listed some of these plants known in Hocking County 30 years ago. Transeau (18), however, has attempted to relate certain events in the physiographic history of the Alleghany and Cum-

¹Paper from the Department of Botany, The Ohio State University, No. 428.

Thanks are due Dr. E. N. Transeau, with whom various phases of the problem have been discussed many times, and who has criticized the manuscript; and Dr. W. Storrs Cole, Department of Geology, Ohio State University, who has made helpful suggestions. The writer also is indebted to Dr. R. T. Wareham, who checked the moss list; and F. H. Norris and E. B. Wittlake, who photographed the topographic maps from which Fig. 1 was compiled.

berland plateaus to the arrival and present distribution of these disjunct species which include "flowering plants, conifers, ferns, mosses, lichens, and algae."

It is the purpose of this paper to list these southern and Appalachian species and to further examine the pre-historic factors which appear to have been associated with their migration into the area, and also with their later isolation. The following is a list of plants occurring at one or only a few isolated stations in the unglaciated plateau. The more widely distributed species have been omitted.²

ALGAE

Mesotaenium aplanosporum Taft. Known only at Lloyd Bridge mine, Jackson county (14).

FUNGI

Scleroderma geaster Fr. Hamilton, Ross and Jackson counties.

LICHENS

Sticta feei Del. Fide C. W. Dodge.

Gyrophora dillenii (Tuck.) Müll. Arg. Several other species might be included on the basis of our present knowledge of distribution, but they are inconspicuous crustose plants such as *Lecanora deplanans* Nyl., known in West Virginia, but elsewhere only in Hocking County, Ohio. The *Gyrophora* however, is a large rock tripe and has been thoroughly searched for in southern Ohio. It has been found in Hocking, Fairfield, Vinton, Meigs and Lawrence counties. The *Sticta* is known only from Highland county and according to C. W. Dodge of The Missouri Botanical Garden, is known elsewhere only along the Atlantic Coastal plain.

MOSSES

Atrichum crispum (James) Sull. Jackson county.

Brothera leana (Sull.) C. Mull. Fairfield, Hocking, Jackson and Pike counties.

Campylopus flexuosus Brid. Jackson county.

C. introflexus (Hedw.) Brid. Jackson county.

Dichelyma capillaceum Bry. Eur. Jackson and Ross counties.

Dicranum condensatum Hedw. Hocking, Jackson and Adams counties.

D. spurium Hedw. Hocking, Jackson and Athens counties.

Grimmia pilifera Beauv. Hocking, Jackson and Scioto counties.

Fabronia ravenelii Sull. Ross county.

Fissidens garberi Lesq. & James. Hocking and Jackson counties.

Pleuroidium acuminatum Lindb. Hocking, Jackson and Ross counties.

²Nomenclature followed in these lists is that of Fink (2) for the lichens; Grout (5) for the mosses; Schaffner (11) for the ferns and flowering plants. All of the plants listed are in the Ohio State University Herbarium and have been seen by the writer, unless otherwise indicated.

Pogonatum brachyphyllum (Rich.) Beauv. Hocking county.
Nanomitrium austinii (Sull.) Lindb. Jackson county.
N. synoicum (James) Lindb. Jackson county.
Philonotis longiseta (Rich.) E. G. Britton. Hocking county.
Sciaromium lescurii (Sull.) Broth. Hocking and Jackson counties.
Syrophodon taxanus Sull. Hocking, Jackson and Pike counties.
Weisia tortilis (Schwaegr.) C. Müll. Adams county.
Zygodon viridissimus (Dicks.) R. Br. Jackson county.

Ranges of all the above species are indicated by Grout (4).

FERNS

Lygodium palmatum (Bernh.) Sw. Hocking and Athens counties; only two stations in Ohio.
Trichomanes boschianum Sturm. Spruce Run, Hocking county.
Polypodium polypodioides (L.) A. S. Hitchc. Reaches northern limit in Ohio in Hocking county. Also in Meigs, Hamilton and Gallia counties.
Asplenium resiliens Kunze. A single station in Adams county.

FLOWERING PLANTS

Wolffia papulifera Thomps. In a small pool, Salt Creek, Jackson county. Possibly entered state via the Mississippi embayment but persisted only in this locality.
Cyperus refractus Engelm. Jackson county.
C. retrofractus (L.) Torr. Jackson and Hocking counties.
C. lancestriensis Port. Jackson and Meigs counties.
C. torreyi Britt. Jackson county.
Muhlenbergia capillaris (Lam.) Trin. Jackson county.
Gymnopogon ambiguus (Mx.) B. S. P. Jackson county.
Panicum verrucosum Muhl. A single station in Adams county.
P. yadkinense Ashe. Jackson and Scioto counties.
P. anceps Mx. Jackson county.
Paspalum longipedunculatum Le Conte. Jackson county.
Erianthus divaricatus (L.) Hitchc. Scioto county.
Iris verna L. Scioto county.
Stenanthium robustum S. Wats. Fairfield, Jackson and Scioto counties.
 Taken also in Stark county, on a steep hillside in open field.
Hexalectris spicata (Nutt.) Barnh. Adams and Scioto counties.
Magnolia macrophylla Mx. Jackson county.
M. tripetala L. Hocking, Jackson, Vinton and Scioto counties.
Ranunculus alleghaniensis Britt. Morgan and Vinton counties.
Draba cuneifolia Nutt. Adams county.
Polygala curtissii A. Gr. Jackson county.
Hibiscus oculiroseus Britt. Lawrence, Jackson and Pickaway counties.
 Another species that may have reached Ohio from the Mississippi embayment region.
Triadenum longifolium Sm. Jackson and Vinton counties.
Passiflora incarnata L. Lawrence county.
Silene rotundifolia Nutt. Jackson, Hocking, Ross and Pike counties; on ledges and in crevices in deep gorges.

- S. wherryi* Sm. Highland, Adams, Pike and Scioto counties.
Calycanthus nanus (Loisel.) Sm.
Robinia hispida L. Jackson, Athens, Meigs, Highland and Muskingum counties.
Clitoria mariana L. Jackson, Fairfield, Adams and Scioto counties.
Galactia volubilis (L.) Britt. Jackson, Scioto and Adams counties.
Ilex opaca Ait. Gallia and Lawrence counties.
Heuchera villosa Mx. Gallia, Adams and Lawrence counties.
Rhamnus caroliniana Walt. Adams and Scioto counties.
Euonymus americanus L. Jackson, Vinton and Gallia counties.
Pachystima canbyi Gr. Highland county.
Quercus prinoides Willd. Adams county.
Q. ilicifolia Wang. Not known in Ohio, but grows across the river from Lawrence and Scioto counties.
Q. triloba Mx. Lawrence and Scioto counties.
Kneiffia linearis (Mx.) Spach. Jackson, Scioto and Meigs counties.
Azalea lutea L. Jackson, Fairfield and Lawrence counties.
A. nudiflora L. Lawrence, Scioto, Ross and Jackson counties; also in northern Ohio in Portage, Geauga and Ashtabula counties.
Rhododendron maximum L. Jackson, Fairfield, Scioto, Lawrence and Hocking counties. Numerous stations in western Hocking county.
Xolisma ligustrina (L.) Britt. Gallia and Ross counties. Grows in a bog in Gallia county.
Styrax grandifolia Ait. Near "Buffalo Beat" in Athens county, "on an outcropping ledge of limestone."
Halesia carolina L. Scioto county.
Phlox stolonifera Sims. Hocking, Jackson and Athens counties.
Chionanthus virginica L. Jackson, Gallia, Meigs, Lawrence and Scioto counties.
Asclepiadora viridis (Walt.) A. Gr. Adams, Meigs and Highland counties.
Gentiana villosa (L.) Sm. Adams, Scioto, Jackson and Gallia counties.
Anisostichus capreolata (L.) Bureau. Adams, Scioto and Lawrence counties.
Ruellia parviflora (Nees.) Britt. Meigs and Gallia counties.
Scutellaria serrata Andr. Hocking, Jackson, Athens and Gallia counties.
S. integrifolia L. Hocking, Vinton, Jackson, Ross, Scioto and Lawrence counties.
S. saxatilis Ridd. Scioto county.
Koellia pyncnanthemoides (Leav.) Ktz. Scioto and Jackson counties.
Meehania cordata (Nutt.) Britt. Hocking, Gallia, Scioto, Meigs and Athens counties.
Diodia virginiana L. Adams county.
Viburnum venosum Britt. Jackson county.
Coreopsis major Walt. Gallia, Lawrence and Scioto counties.
Antennaria solitaria Rydb. Ross, Jackson, Hocking, Lawrence, Adams and Vinton counties.
Chrysopsis mariana (L.) Ell. Scioto, Gallia, Jackson, Vinton and Hocking counties.
C. graminifolia (Mx.) Ell. Adams county.

Seriocarpus linifolius (L.) B. S. P. Scioto, Adams and Jackson counties.
Eupatorium album L. Scioto and Jackson counties.
E. torreyanum Short. Jackson county.
E. rotundifolium L. Jackson, Hocking and Fairfield counties.
E. pubescens Muhl. Hocking county.
E. aromaticum L. Scioto, Fairfield and Jackson counties.
E. incarnatum Walt. Lawrence county.
Vernonia noveboracensis (L.) Willd. Gallia county.

The above lists include species of plants which are definitely disjuncts, or in a few instances, species which are at the northern edge of their range in Ohio. They occur at stations in 14 southern Ohio counties, but it is notable that all of them grow in, or *adjacent to*, areas of considerable elevation in western Gallia and eastern Lawrence counties, Adams and Scioto counties, the rock shelter region in western Hocking county, and Liberty Township in Jackson county. Moreover, over 60 per cent of the vascular plants listed occur in the Hocking or Jackson county stations. More than half of them have been taken in Liberty Township.

To account for the localized distribution of these plants, several phenomena should be taken into consideration. These are:

1. The migration of southern species into the area.
2. The isolation of assemblages of southern plants in several clearly delimited areas.
3. The conspicuous absence of flood plain, swamp forest, and other lowland species from the list.
4. The survival of these species since the time of their arrival. This is a distinct problem which can be solved only by a detailed study of edaphic and microclimatic conditions in the places of survival.

Southern plants probably have reached Ohio along the hilltops and ridges of the Cumberland Plateau across the route of the present Ohio River, and by way of the flood plains and adjacent bluffs of the preglacial Teays River system, the headwaters of which were far to the southeast in western North Carolina. By which route the individual species arrived is uncertain, but it seems reasonable that the Teays and other rivers with headwaters in the plateaus and mountains have been effective agencies of migration and that many southeastern species were living in the plateau of Ohio long before the coming of Pleistocene ice. The arrival in this region of these species is, in fact, far more likely to have occurred during the long time the Teays River was in existence than later. If a southeastern

flora had not arrived in the area during the 60,000,000 years of the Tertiary when these streams were potent propagule-carrying agencies, then it is not likely that these plants would have arrived in postglacial time after the elimination of these agencies.

Thus it may be assumed that the southern and southeastern flora was well established in the region at the close of the Pliocene and that the present occurrence of individual species in Ohio, and the absence of others, may be accounted for by events since that time. The story of drainage changes as first assembled by Tight (16) and more recently summarized by Rich (21), and Stout and Lamb (12), is probably incomplete. Nevertheless, the major events seem well enough understood to associate their effects with the history of Ohio vegetation. These events may be listed as follows:

1. Advance of an early continental ice sheet.
2. Blocking of northwestward flowing streams by this advance.
3. Ponding of drainage water from the plateau in the valleys of the Teays and Licking (Ky.) systems and the accumulation of slackwater deposits in them.
4. Development of new outlets by the ponded water across low divides, and the reversal of drainage.
5. Withdrawal of the early ice sheet and subsequent re-advances of continental ice.
6. Modification of silts and clays by subsequent drainage from the glaciers.
7. Establishment for a time of a Deep Stage during an interglacial period by the pronounced downcutting of the newly-formed Ohio River and its tributaries.
8. Carving of terraces in the filled valleys and partial removal of slackwater deposits by interglacial and present-day streams.

With the blocking of the northwestward flow of the Teays river by ice, a vast lake, with a complex of irregular branches was formed. An estimate of one stage in the extent of this ponded water is presented in Figure 1. "Lake Tight" existed for a considerable time as is indicated by the 80 foot depth of the lacustrine deposits in many of the preglacial valleys of southern Ohio (13, 21). That its level was subject to periodic and great fluctuations prior to the establishment of an outlet across a low divide, is indicated by the presence of lake shore terraces (16) and the occurrence of a number of erratics in Kentucky (7, 9), some more than 50 miles south of the known glacial boundary. One glacial boulder, weighing approximately

16 tons (7, 8), is located at an elevation of 1009.3 feet. All of the erratics have been found within the area of ponding at or near the heads of preglacial valleys, where it is reasonable to suppose icebergs would be more likely to accumulate. All of the lake deposits, on the other hand, are at, or below, the 860 foot level.

According to the records obtained during the floods of recent years in the Ohio valley, the Ohio River with its present outlet, rose 80.1 feet at Cincinnati, as a result of heavy precipitation on the snow-covered mountains in the Ohio basin to the east. Lake Tight existed for a long time with no outlet comparable to that of the present Ohio, and was supplied with water not only from the plateau, but also by meltwater from the vast ice sheet and snow fields to the north.

EFFECTS ON VEGETATION

This and subsequent events seem to have been decidedly significant in their effect on existing vegetation and on the later development of vegetation in the following ways:

1. The destruction of all lowland plants in the area of ponding. The absence in these areas of plants limited in their distribution to flood plains, swamps and other lowland habitats is significant.

2. Isolation of certain upland species on islands and peninsulas within the ponded area (Fig. 1). It is not assumed that these plants are necessarily still restricted to these upland areas. Many are now found at lower levels in coves, on ledges and steep slopes, and even in gorges within the areas previously mentioned.

3. The destruction of an important agency of migration with the elimination of the Teays River and the subsequent drainage changes which occurred with the reversal of the preglacial streams of Ohio.

4. Modification of air temperatures and lengthening of the frost-free season over and adjacent to the ponded area due to the high specific heat of water and the increase of atmospheric moisture. Present day effects of much smaller water areas (*e. g.*, Ohio River, Lake Erie) is well known (10).

5. Degradation of deep gorges with the ultimate overflow of the ponded water over a low divide somewhere to the west. This produced a great diversity of plant habitats, with a wide range of local climatic conditions,³ some favorable to the requirements of southern species. Other factors favored boreal species which arrived later. Thus it is not uncommon in western Hocking county to find a number of southern plants and as many boreal species in the same gorge.

³Measurement of some of these microclimatic conditions in one valley over a continuous period, an investigation now in its third year, is being carried on by three members of the Department of Botany, Ohio State University. Significant data are being obtained, but are too detailed for presentation here.

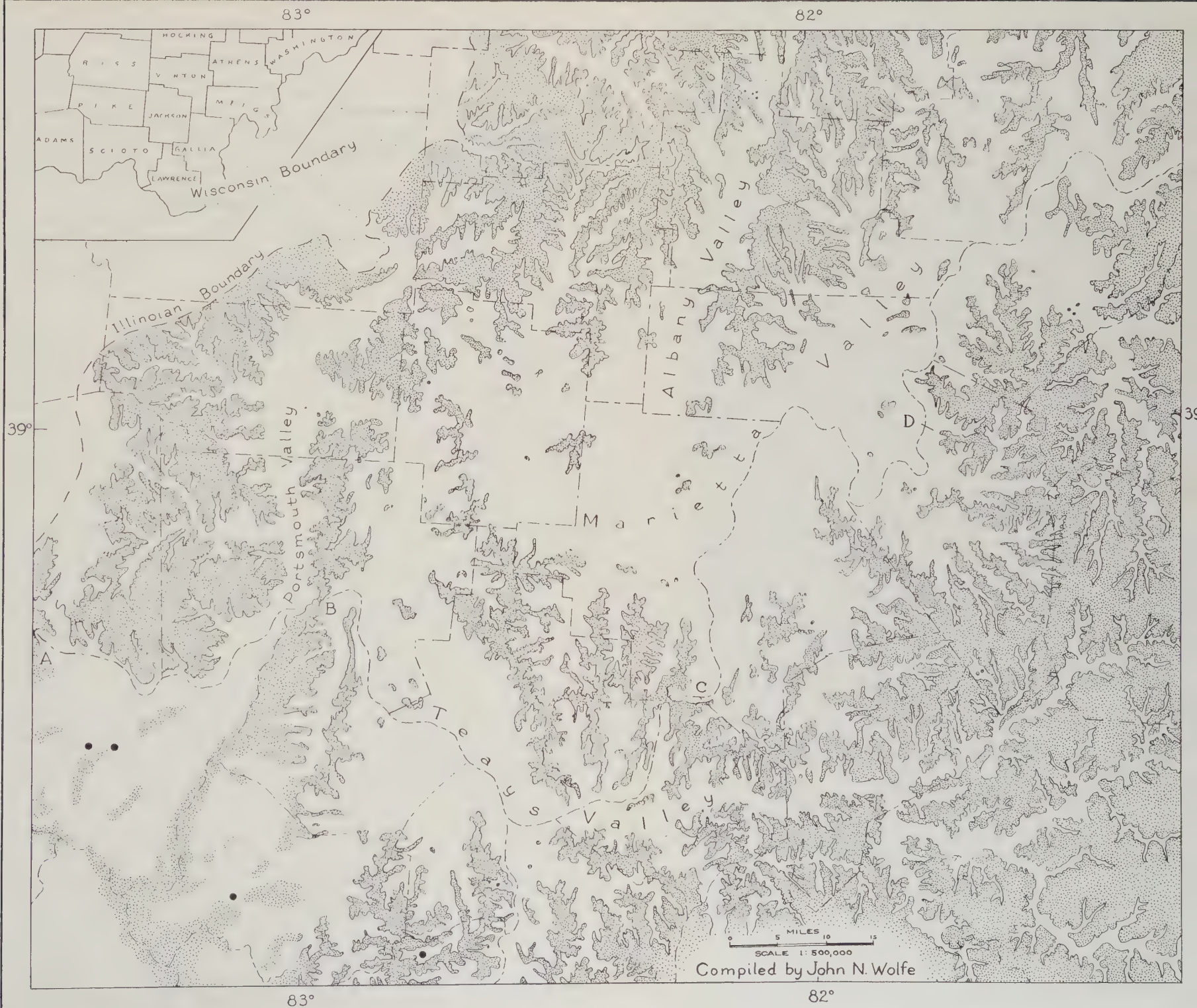


FIG. 1. Sketch map showing one possible stage in the extent of proglacial Lake Tight in southern Ohio and adjacent parts of Kentucky and West Virginia. Also indicated are the principal valleys of the Teays System in Ohio, and the preglacial divides across what is now the Ohio River (A, B, C, D). The large dots show the location of four glacial boulders outside the drift boundaries. Inset: County map of southern Ohio.

This estimate of Lake Tight was compiled from 50 U.S.G.S. topographic maps of the area, the 900 foot contour line being used in outlining the flooded area. Some allowance has been made for post-glacial erosion and some of the important preglacial divides have been reconstructed.

6. Filling of valleys with valley train gravels by subsequent glaciation, and the deposition of calcareous clays over vast areas, conspicuously modified local edaphic conditions. The migration of plants, favored by conditions associated with alkalinity, far into the highly acid Blackhand sandstone region of Hocking county, along the lower slopes and valley bottoms, illustrates this point. Examples: Fringed Gentian and Redbud.

7. Carving of terraces in the valley fills further modified conditions by removal of lacustrine deposits and valley train gravels, and resulted in better drainage on the terraces.

CONCLUSION

Thus, on the basis of available data, the presence of a large number of isolated Appalachian and southern species of plants are known in the southern Ohio area. The arrival of these species, their isolation in three or four rather well-defined areas, and their persistence may be associated with a succession of events in the physiographic history of the region.

It should be understood, of course, that the list of plants as published, is tentative. Some names may be removed altogether and the arrival and distribution of some of the species may later be accounted for by a different combination of events. The writer is not unaware of the fact that an understanding of the vegetation of Ohio is dependent upon a detailed knowledge of the historical factors. This story has not yet been written and the discovery of its successive episodes will require the combined efforts of geologists, pedologists, zoologists and botanists.

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Medical Genetics

The staff and students of Duke University School of Medicine deserve the thanks of the medical profession, practising physicians as well as medical students, for having persuaded Professor Snyder to publish in book form a series of lectures on medical genetics which he presented to the Medical Schools of Duke University, Wake Forest College and the University of North Carolina. They have rightly felt that the way Professor Snyder has chosen to give information on the subject is unique. They might have expected beforehand, as most medical men do, to be presented with the results of crossing experiments with plants and animals and their highly hypothetical bearing on human beings, with statistical findings and a mass of mathematical formulas. They might have thought of medical genetics as a branch of science quite apart from every-day medicine. Readers of the book, however, will be amazed by the fact, as obviously have been the audiences of the lectures, that the material is truly medical, with no elaborate introduction dealing with genetic "theories," no mention of *Drosophila* or other experimental material, and no "statistical data."

The book from its first pages deals with practical problems, with the application of genetics to medical conditions, and with questions the highly important bearing of which even the youngest medical student understands. The medico-legal applications of genetics, the genetic background of mental disorders, of disease, of abnormalities of the eye and ear, of the skeleton, of the muscles, of the blood and of diatheses are among the main points discussed. In giving the present status of our knowledge of the genetic factors concerned in these conditions, the author does not fail to outline critically the important role which environmental factors play in modifying the expression of hereditary traits in man. Since human beings are given the opportunity to control to a large extent their environment, a change is offered to the physician of the future to control, by a knowledge of the interaction of the factors involved, the expression of certain traits in man by providing suitable environments in certain cases.

The author summarizes in excellent systematic tables what is known of the hereditary nature and the mode of transmission of many groups of diseases and abnormal conditions. In these tables are tabulated as well those conditions about which nothing genetic is known at present, in such a way as to set off the genetic conditions in proper perspective in the whole field of medicine. In addition to its many advantages thus far discussed, the book provides the reader with a fine source of genetic orientation of value to the busy medical man. Carefully chosen family histories illustrating the main kinds of genetic behavior, and some good photographs of rare genetic conditions make the book even more readable.—*F. Blank, M.D.*

Medical Genetics, by Laurence H. Snyder. x+130 pp. Durham, N. C., Duke University Press, 1941. \$1.50.

QUANTITATIVE EFFECTS OF VITAMIN A DEFICIENCY ON THE SPINAL AND SYMPATHETIC GANGLIA

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Since lesions of the nervous system due to avitaminosis were first reported by Mellanby ('26) there have been numerous papers dealing with the degenerative changes following experimental deprivation of the various vitamins in animals. These papers have reported several different types of effects, varying from moderate swelling of nerve fibers to definite degeneration, haemorrhage into various parts of the nervous system, and irritative or inflammatory changes not definitely degenerative in character. Many of the reports are contradictory. Most of the studies have been made with the usual neurological stains, such as Marchi, Speilmeyer's, and Sudan III. Thus Grinker and Kandel ('33) studied nerves from vitamin A deficient rats but found no changes in the nerve fibers. Hughes, Aubel and Lienhardt ('28) reported finding degeneration in cows, chickens and pigs. Aberle ('34) described extensive degeneration in brachial and sciatic nerves in rats on vitamin A deficient diets. Mellanby ('34) reported degeneration in dogs in vitamin A deficiency. His observation of degeneration in the posterior roots of spinal nerves and its absence in anterior roots led him to the hypothesis that the xerophthalmia which occurs in this disease is due to loss of sensory nerve supply. He also assumed a special selective action in the case of afferent fibers while efferent fibers were not affected. This does not accord with the observed symptoms of deficiency. These have been described by several investigators, including ourselves (Sutton, Setterfield and Krauss, ('34), Setterfield and Sutton, ('35), using the polarized light technique. This has been corroborated by Lee and Sure ('37). The flaccid paralysis and muscle atrophy accompanying this avitaminosis indicates destruction of efferent nerve fibers to the muscles affected. The loss of sense of pain and touch which occurs at the same time is explained by the observations on nerve fibers already published by us and by the results of the present study.

In this paper we wish to present further evidence that vitamin A deficiency causes definite and measurable destruction of peripheral nervous tissue sufficient to explain the loss of function already noted. Reference should be made to our previous publications for the roughly quantitative observations of degeneration in nerve fibers.

METHODS AND MATERIALS

In the present study we have made total cell counts of certain of the spinal ganglia of normal control and vitamin A deficient white rats¹. The serial sections of the ganglia were stained with haematoxylin and eosin and counted at a magnification of 900 diameters. A cross-hatched disc in the ocular made possible accurate counting of the cells. The nucleoli only in each section were counted since the cells are so large that they appear in several successive sections.

For this study forty-three ganglia were used, these being the second, third and fourth lumbar ganglia in all cases. They were distributed as follows: three normal second lumbar; three normal third lumbar; five normal fourth lumbar; eleven deficient second lumbar; nine deficient third lumbar and twelve deficient fourth lumbar. Control and experimental animals were litter mates and all the experimentals had been on the deficient diets from 55 to 64 days. All showed symptoms of paralysis (flaccid) and loss of sensation of pain and touch though in varying degrees. All were near death at the time of cancellation.

RESULTS AND COMMENT

Little is known as to the usual or normal number of cells in any spinal ganglion of any animal. A few studies have been made, notably that of Hatai ('02) on the white rat. In trying to determine the normal number of cells in the spinal ganglia at different ages he counted the cells of the sixth cervical, fourth thoracic, and second lumbar at four different ages. The rats used ranged from 10.3 grams weight to 167 grams. His figures are averages of each ganglion at the four ages used. It is of interest at this point that his average of the counts of the second lumbar differs by only 130 cells from our average given below. This close correspondence gives greater confidence that our counts are substantially correct.

Nerve cells in vitamin A deficiency show characteristic degenerative changes preceding their actual death and disappearance. In about the order of their occurrence these include gradual loss of staining qualities, shrinkage, pyknotic nuclei, eccentric nuclei, loss of the typical concentric arrangement of the cytoplasm, indistinct cell outlines, fading and disappearance of the nuclear membrane, and finally loss of the nucleolus. At about this time the cell is damaged beyond recovery.

¹The diet used in this experiment was the standard U.S.P. XI, except that the casein was not extracted but contained a minute amount of vitamin A. Control animals received an adequate supplement amount of cod liver oil.

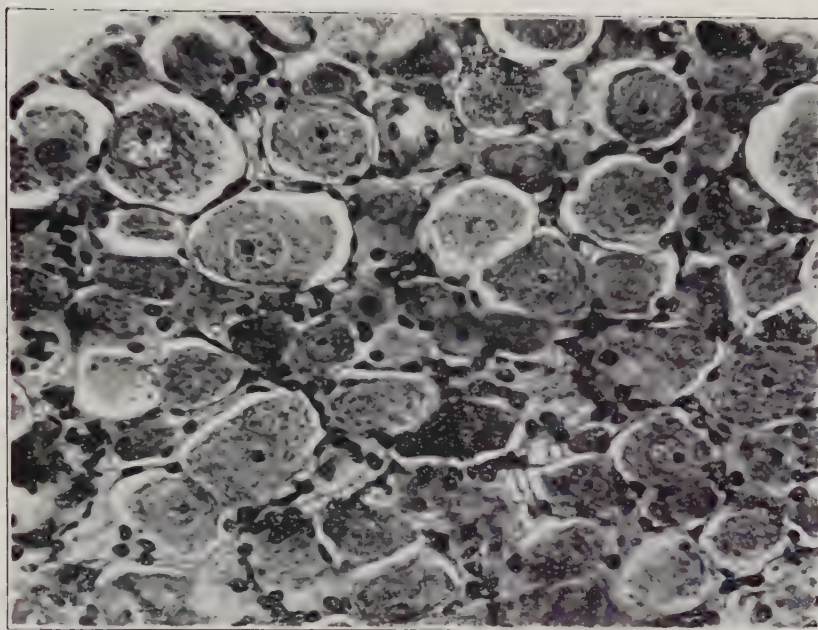


FIG. 1. Section of normal spinal ganglion of white rat. $\times 900$.

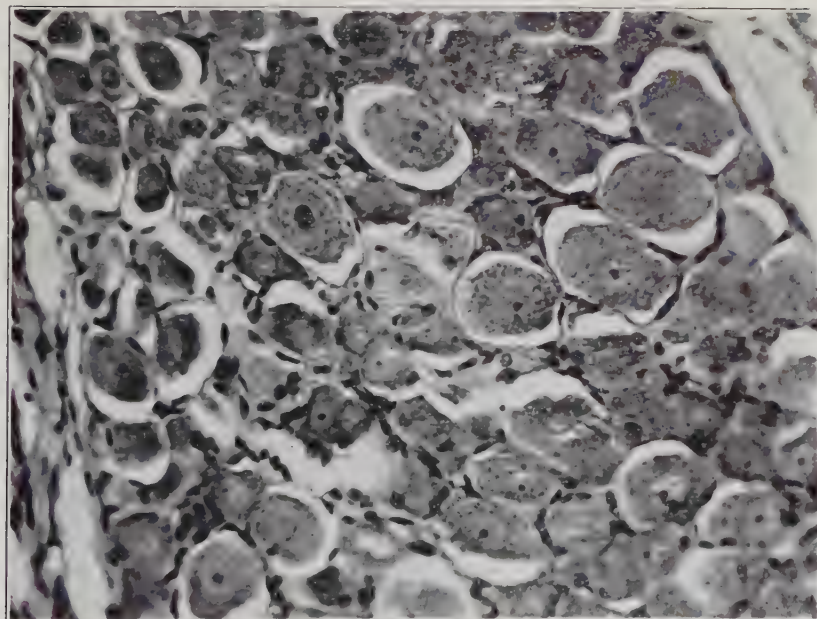


FIG. 2. Section of spinal ganglion of a vitamin A deficient white rat. Note extensive shrinkage and indistinct cell and nuclear outlines. $\times 900$.

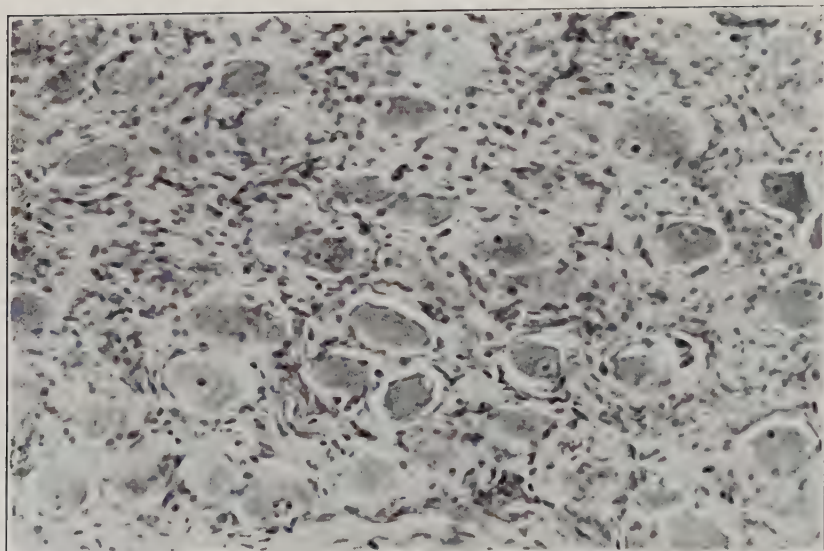


FIG. 3. Section of normal inferior cervical sympathetic ganglion of yearling calf. $\times 900$.

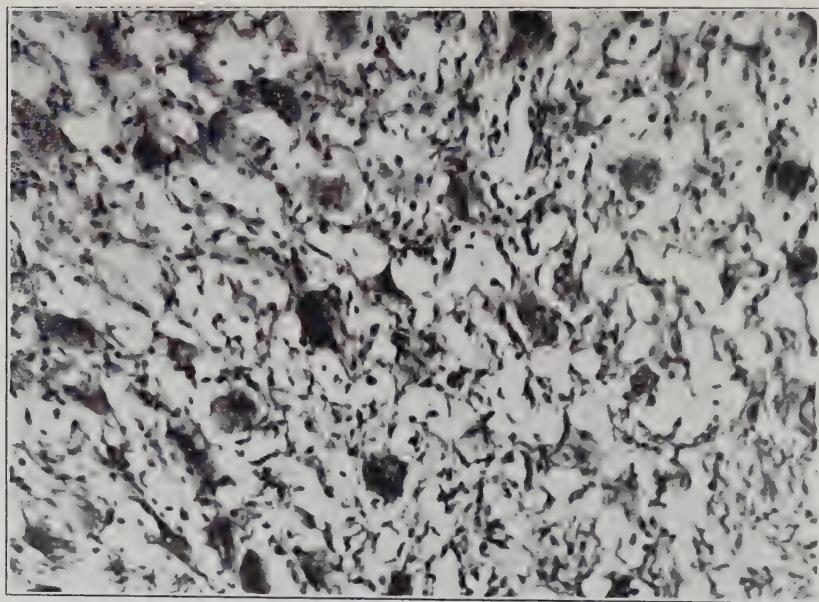


FIG. 4. Section of inferior cervical sympathetic ganglion of a one-year-old vitamin A deficient calf. $\times 900$.

All of these changes occurred in the ganglia studied though not to the same degree in all the cells. Figure 1 illustrates the appearance of normal spinal ganglion cells in our series. Comparison with Figure 2 shows the effects of the deficiency. Most of the changes named above are to be seen in the cells of this section. The area photographed is quite typical of the ganglia of deficient animals. Most noticeable are the great shrinkage and the loss of distinctness of cell and nuclear outlines.

TABLE I
EFFECTS OF VITAMIN A DEFICIENCY ON THE SPINAL GANGLIA

NORMAL CONTROLS			VITAMIN A. DEFICIENT 55 TO 64 DAYS; SHOWED LOSS OF SENSIBILITY AND FLACCID PARALYSIS		
L-2	L-3	L-4	L-2	L-3	L-4
7918	6148	7453	7072	5743	6424
8085	9333	8354	6456	3862	6536
8737	9444	8403	6218	5840	4942
		8355	4934	6001	7782
		8457	5131	5385	6466
			6687	5858	6259
			5985	5905	6142
			3044	5763	6965
			6412	7899	7142
			6151		7070
			6395		7186
					7173
Average 8246	8308	8204	5862	5806	6674
Percentage of cells lost.....			29%	30.2%	18.7%

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Sum of Squares	Variance	F Value
Vitamin Content.....	1	6,862,981	6,862,981	37.88**
Ganglia.....	2	195,848	97,924	.54
Interaction.....	2	281,583	140,791	.78
Error (within classes).....	37		181,178	

The actual total numbers of cells in the normal and deficient ganglia are shown in Table I. The average of the different ganglia show the considerable lowering of the total number of cells present in the deficient cases. The percentages indicate a loss of from 18.7% to 30.2%. That these percentages are significant from the statistical standpoint is shown in the Analysis of Variance included in the table. The analysis proves that the factor responsible for the loss is the lack of vitamin A and that

the differences between normal and experimental animals are not due to errors in counting or chance variation among the ganglia used. As a matter of fact, recounts of many of the ganglia showed that the total is accurate to within 100 cells.

A short time before these cell counts were completed Mellanby ('38) reported that there was an overgrowth of new bone about the foramina of the skull and presumably those of the vertebral column. He suggested that the degeneration found in nervous tissues of vitamin A deficient animals might well be due to pressure of the bone growth on the nerve fibers as they pass through the foramina or on the ganglia themselves if surrounded by bone as in the spinal column.

This appeared to this writer to be a valid criticism of earlier reports. In an attempt to confirm or refute Mellanby's theory observations were made on the ganglia of the sympathetic chain of vitamin A deficient animals. In this location no pressure is possible on either cells or fibers. The material used consisted of ten ganglia of the sympathetic trunk from yearling calves reared on a diet completely deficient in vitamin A. At the end of a year the deficient animals (two) were emaciated, one was completely blind and the other nearly so, and the germinal epithelium of the testes was practically destroyed. New bone growth was found at the optic foramen, that of the blind animal being constricted to about two millimeters in diameter. This, of course, is in line with Mellanby's findings referred to above.

Sections of the inferior cervical sympathetic ganglia showed only moderate degenerative changes in one animal (partially blind) but in the blind calf the changes were so extreme that scarcely any cells were found which could be judged normal. Photographs are reproduced herewith to illustrate the normal and deficient ganglia. No attempt was made to make counts of the ganglion cells due to the lack of discreteness of the ganglia and the enormous number of cells present. In view of the structural changes evident in the photographs it hardly seems necessary.

CONCLUSIONS

The evidence submitted in this report shows that lack of vitamin A causes highly significant reduction in the total number of ganglion cells in the white rat.

The evidence further shows that there is extensive destruction of cells in sympathetic ganglia also in vitamin A deficient calves.

These observations account for the nerve fiber degeneration already reported since death of the cell bodies would inevitably result in degeneration of their processes.

Finally, while bone growth may be a factor in causing degeneration, Mellanby's theory of bone pressure as the principal cause of degeneration in nervous tissue is not acceptable since it occurs in ganglia where pressure is not a factor.

ACKNOWLEDGMENTS

The writer is indebted to the Graduate School of the Ohio State University for financial aid in the work of cell counting and to Dr. T. S. Sutton, of the Department of Animal Husbandry, for the animals used in this study.

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A Lot of Insects

Mr. Lutz in his characteristic style presents a lot of interesting facts and fancies about a lot of insects on a town lot in his new book entitled "A Lot of Insects." This type of publication presented in a fascinating, popular manner, yet scientifically accurate, is a valuable contribution in the field of entomology. It will help to build "good will" toward pure and economic entomology.

Mr. Lutz has been a leader in the popularization of entomology in his part of the world. Perhaps no area of like geographical size possesses more amateur entomologists than the metropolitan district of greater New York. This remarkable story of 1402 species of insects taken from a 75 by 200 foot town lot is fascinating for a taxonomic entomologist, almost unbelievable to an economic entomologist and beyond belief to the uninitiated.

The reviewer, whose fundamental interest in entomology is biological control, has been highly entertained by the comments and ideas presented which deal with artificial control versus biological control. Lutz is a strong advocate of biological control and this is clearly evident in his terse and significant comments on this subject.

Most economic entomologists deal with a group of insects which in numbers are less than one percent of all species. Again many entomologists devote a large proportion of their time on one insect. For these entomologists a book by a man who is highly versed in the devious ways and habitats of many insects that are not economic should prove to be very refreshing and thought provoking. This book will help to create interest in the insects in the reader's own back yard. For the amateur, the teacher, or professional entomologist, many or all chapters are exceedingly stimulating and highly entertaining.—*Alvah Peterson.*

A Lot of Insects, by Frank E. Lutz, 308 pp., many illustrations. New York, G. P. Putnam's Sons, 1941. \$3.00.

SOME NEW SPIDERS FROM OHIO

W. M. BARROWS AND WILTON IVIE

Of the five species described below four are apparently undescribed while the fifth, *Phrurolithus fratellus* Gertsch was originally described from a female specimen from Texas. (Am. Mus. Novitates No. 805, p. 6). The types are retained in the University of Utah collection.

Dipoena munda Barrows and Ivie, n. sp.

(Plate I, Figs. 1-5)

Carapace blackish brown. Chelicerae, endites, labium, and sternum dark brown to blackish. Palpi blackish brown. Legs light brownish yellow, with a broad black stripe along the anterior side of each femur, and a similar stripe along the posterior side of tibia-patellae III and IV, these latter stripes usually extending along posterior side of the femur for part of its length. Abdomen black with five white spots above, one on each side near base, one on each side near middle, and one just above the spinnerets. Middle area of venter light gray, usually with a white spot on each side.

The female is without special modifications in structure. The male has the cephalothorax nearly circular in outline; the whole of it elevated; median depression sunken. Clypeus high, about six times the diameter of the anterior lateral eye.

Measurements:	Female	Male
Length.....	2.50 mm.	2.10 mm.
Carapace:		
Length.....	.88	.95
Width.....	.67	.81
Tibia-patella:		
I.....	.65	.67
IV.....	.80	.83

Type locality: Rockbridge, Ohio. Male holotype, female allotype, male paratype. W. M. Barrows collector.

Phrurolithus fratellus Gertsch

(Plate I, Figs. 6-7)

Male.—Carapace and chelicerae light brownish yellow without distinct markings. Endites, labium, sternum, legs, and palpi pale yellowish, without markings. Abdomen light yellowish gray, with some lighter chevron-like marks above. Venter much lighter.

Structure very similar to that of other members of this genus, the main distinguishing feature being the palpus. See figures.

Measurements: Length 1.60 mm.; carapace, length .75 mm., width .63 mm.; tibia-patella I .80 mm., IV .77 mm.

Type locality: Columbus, Ohio. Male holotype. May 27, 1925. W. M. Barrows collector. Along river, in ants nest.

***Micaria gertschi* Barrows and Ivie, n. sp.**

(Plate I, Figs. 8-9)

Male.—Carapace orange brown with dusky markings, consisting of fine specks over the entire surface, marginal shadings, radial lines, and a design on the posterior part of the head, as in certain other species of this genus (*quinquenotata* Em., etc.). Chelicerae reddish brown. Endites, sternum, and coxae of the legs brownish orange; labium similar, but more dusky. Legs darker, due to a dense covering of appressed pubescence. Abdomen glossy greenish black above, with a transverse band of light gray near middle. Venter lighter and more grayish. Epigastric region orange brown.

Structure similar in general to that of *M. gentilis* Banks, with which it also agrees in size. Minor differences in color and the structure of the male palpus will separate the two. The tibia of the palpus has a small sharp process on the dorsal side at the distal end. The hook of the palpal organ is near the distal end.

Measurements: Length 3.90 mm., carapace, length 1.90 mm., width mm.; tibia-patella I 2.0 mm., IV 2.0 mm.

Type locality: Columbus, Ohio. Male holotype. July 7, 1935. W. M. Barrows collector.

***Dictyna zaba* Barrows and Ivie, n. sp.**

(Plate I, Fig. 10)

Male.—Carapace brown, with dusky radial streaks on thoracic part. Chelicerae and endites reddish brown. Sternum and labium dusky brown. Palpi light brownish. Legs pale yellow, with very faint annuli at distal end of tibia and metatarsus. Abdomen gray, with an indistinct pattern above, somewhat as in *muraria* Em. Venter dark gray.

A small species belonging to the *sublata* group. Cephalothorax typical; height of clypeus two diameters of an anterior lateral eye. Anterior eye row straight; AM eyes one and one-half diameters apart, about a radius from the side eyes. Posterior row slightly recurved; PM eyes about a diameter apart, a little farther from the side eyes. Median ocular area about square, as wide in front as behind. Chelicerae typical; the median opening not as wide as the diameter of a chelicera. Labium longer than wide. Endites slender, converging around labium; tips nearly touching. Sternum broadly chordate; as wide as long. Legs slender. Abdomen typical.

Measurements: Length 1.85 mm.; carapace, length .88 mm., width .65 mm.; tibia-patella I .93 mm., IV .67 mm.; chelicerae .42 mm.

Type locality: Hocking County, Ohio. Male holotype. W. M. Barrows collector.

Tapinocyba emertoni Barrows and Ivie, n. sp.

(Plate I, Figs. 11-14)

Male.—Carapace brownish orange, markings indistinct. Chelicerae, labium, and sternum brownish orange. Endites lighter. Legs light brownish orange, with the patellae and distal ends of the femora slightly lighter. Abdomen dark gray marked with pale gray specks, and curved transverse lines on posterior part. Epigastric region whitish. Spiniferets pale brownish yellow.

Carapace of nearly normal shape—the head is not elevated nor otherwise especially modified in shape. Cephalic pit small, situated just behind and above the posterior lateral eye; placed in a narrow groove. Sternum large. Palpus small; embolus short, with tip sharply curved, and tail-piece short and broad.

Measurements: Length 1.1 mm.; carapace, length .54 mm., width .43 mm.; tibia-patella I .43 mm., IV .44 mm.

Type locality: Rockbridge, Ohio. Male holotype, male paratype. March 23, 1928. W. M. Barrows collector.

EXPLANATION OF PLATE

Diplocephala munda Barrows and Ivie, new species.

1. Left palpus, ectal view.
2. Epigynum.
3. Male, dorsal view.
4. Eyes of male, dorsal view.
5. Male cephalothorax, lateral view.

Phrurolothus fratrellus Gertsch.

6. Male palpus, ventral view.
7. Male palpus, ectal view.

Micaria gertschi Barrows and Ivie, new species.

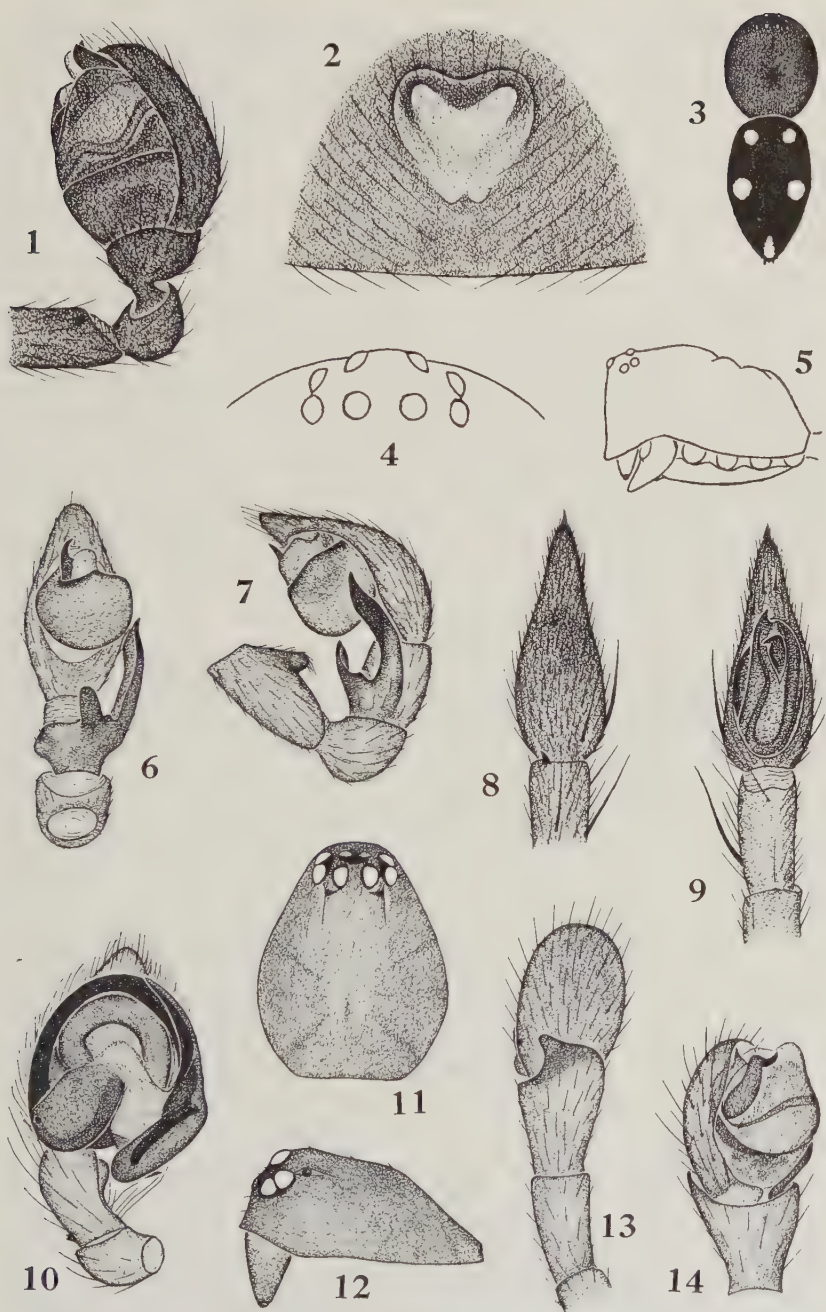
8. Male palpus, dorsal view.
9. Male palpus, ventral view.

Dictyna zaba Barrows and Ivie, new species.

10. Male palpus, sub-mesal view.

Tapinocyba emertoni Barrows and Ivie, new species.

11. Carapace of male, dorsal view.
12. Cephalothorax of male, lateral view.
13. Palpus of male, dorsal view.
14. Palpus of male, ventral view.



LIMNOLOGICAL STUDIES OF WESTERN LAKE ERIE

III. PHYTOPLANKTON AND PHYSICAL-CHEMICAL DATA FROM NOVEMBER, 1939, TO NOVEMBER, 1940

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INTRODUCTION

Limnological studies of western Lake Erie, in the region of the Bass Islands, have been continuous since September, 1938, and these studies with certain modifications will be continued for several consecutive years. Results from the first year's work have been published (Chandler, 1940) and the second year's data will appear in three parts: (1) light penetration and its relation to turbidity (Chandler, 1942), (2) phytoplankton and its relation to general physical-chemical factors, and (3) seasonal and vertical distribution of zooplankton.

It is the purpose of this paper to present quantitative data showing the seasonal variation in abundance and composition of phytoplankton in western Lake Erie, and to show the relation of certain environmental factors to this plankton. Comparisons are made between data of the two years studied in an attempt to show changes in phytoplankton populations as environmental factors change. At present it is not possible to make generalizations in respect to this study, but after pursuing this plan for several years it is hoped that valuable conclusions may be forthcoming. Methods and equipment used in this investigation were essentially those used during the previous year (Chandler, 1940).

The writer is indebted to Leonard J. Bodenlos for field assistance and for chemical data.

PHYSICAL DATA

Annual temperature variations of the surface water are shown in Figure 1. At the beginning of November, 1939, the surface temperature was about 9.0° C. and it declined gradually until it reached a minimum of 0.1° C. in January, 1940, shortly after the ice-cover had formed. This ice-cover attained a maximum thickness of 18 inches and covered most of western Lake Erie from January 10 to April 1. In many respects the ice-cover of the winter of 1940 was different from the

ice-cover of the winter of 1939, and the possible effects of this on phytoplankton production are discussed later. Water temperature under this ice-cover did not exceed 1.5°C ., but it increased gradually with the disappearance of the ice-cover, until a maximum temperature of 25.0°C . was reached in mid-August. Following this maximum the temperature decreased gradually until it reached 11.8°C . in late October, a temperature similar to that of late October, 1939.

Water temperature was quite uniform vertically on a given date, except on three occasions. On May 14, June 5, and June 11, temporary thermoclines were formed, but each was destroyed a few days later by wind action. These thermoclines varied from 1 to 3 m. in thickness and they occurred at various depths from 2 to 8 m. Since these periods of thermal stratification were brief and irregular, and produced small vertical changes in chemical values, we are justified in assuming that thermal stratification is of little importance in this region. Likewise, temperature conditions of the surface water are quite representative of temperature conditions at other depths.

Data pertaining to turbidity and transparency in western Lake Erie from November, 1939, to November, 1940, have been published (Chandler, 1942); therefore, general statements concerning these factors will suffice in the present paper. Curves of turbidity values and Secchi's disc readings are presented in Figure 1. Turbidity values varied from a minimum of 5 ppm., during most of January, February, early March, and for two weeks in June, to a maximum of 60 ppm. in late June. From June to October turbidity at no time was less than 20 ppm.; the average was much higher than for the corresponding period of the preceding year. This turbidity is caused in part by disturbance of bottom sediments through wind action. During this particular year turbidity was highest in summer and autumn, and lowest in winter and spring, but the preceding year was characterized by high turbidity in spring and autumn, and low turbidity during winter and summer.

CHEMICAL DATA

Chemical analyses were made at surface, 5 m., and 9 m. as a regular routine, and analyses at intermediate depths were made when chemical values showed definite vertical variations. In most instances chemical values were nearly uniform vertically; therefore, the graphs for surface values (Fig. 1) give general information concerning chemical conditions from top to bottom on a given date, as well as showing seasonal trends.

Dissolved oxygen in the surface water varied from a maximum of 13.2 ppm. on several occasions in April and May, to a minimum of 7.8 ppm. in August. The oxygen content of the water was high during autumn, winter and spring, and low in summer, as might be expected from data on abundance of phytoplankton (Fig. 2) and on temperature (Fig. 1). Weekly fluctuations in oxygen content during periods of open water were probably due largely to agitation through wave action, but the variations which occurred while an ice-cover was present were probably due to currents. Currents, which are known to exist under the ice, may have moved water with a different oxygen content into

the area investigated, or these currents may have increased the turbidity through agitation of bottom sediments which in turn affected the quantity of oxygen. On December 12, 1939, March 29, and June 22, 1940, high turbidity was associated with low oxygen content. It is likely that the organic sediments present during high turbidity consume oxygen while the inorganic components adsorb oxygen. Vertical distribution of oxygen was not uniform on a given date, but it rarely varied more than 2 ppm. from top to bottom, and often it varied less than 1 ppm. The most pronounced vertical variation occurred on June 11, 1940, at which time a thermocline existed. On this date the oxygen content was above 9 ppm. at surface and 5 m., but at 9 m. it was only 6.5 ppm.; however, a few days later vertical distribution was nearly uniform again.

The pH varied from a minimum of 7.4 in February to a maximum of 8.4 in May, 1940. The graph of surface values in Figure 1 shows that pH was less than 8.0 from early November, 1939, to early May, 1940, and it was 8.0 or more from mid-May to November, 1940. Seasonal changes in pH were similar for the two years of investigation and vertical variation was small except on a few occasions when temporary thermoclines existed.

Free carbon dioxide, from November, 1939, to late April, 1940, was present in quantities varying from 0.5 to 4.2 ppm., and from May until mid-October it was absent except for two collection dates in June and July. From mid-October to November, 1940, free carbon dioxide did not exceed 0.5 ppm., but it was always present. A storm in late June and early July agitated the water from top to bottom, causing bottom sediments to be thrown into suspension; this resulted in a sudden rise in free CO_2 (Fig. 1) as is typical of such disturbances. Data for the present year are similar to those of the preceding year, except that in the former year considerable free CO_2 was present during the entire month of November, while in the latter year it was absent during November. This difference is probably associated with the decomposition of the autumn plankton pulses which were very different in size in the two years. No significant difference in vertical distribution of CO_2 occurred except on July 2, when the surface determination was 0.0, and at 5 and 9 m. the values were 1.0 and 2.0 ppm., respectively.

Methyl orange alkalinity of the surface water varied from 84.0 to 92.0 ppm. from November, 1939, to late April, 1940, and it was less than 84.0 ppm. from late April to June, except on May 14 and 21 (Fig. 1). From June to November, 1940, methyl orange values ranged from 83.0 to 94.0 ppm. The seasonal variation in this factor was approximately the same for the two years of investigation, and vertical variation on a given date was not greater than 2 ppm., except for two collections in March. These differences were probably caused by melted ice and snow running into the open hole through which water samples were taken.

Ph-th alkalinity values for the surface water (Fig. 1) were 0.0 from November, 1939, to the second week in May, 1940. From mid-May until mid-October these values were irregular from week to week ranging from 0.0 to 5.3 ppm., and during late October the values returned

to 0.0. The relationship of Ph-th alkalinity to free CO_2 is shown graphically in Figure 1.

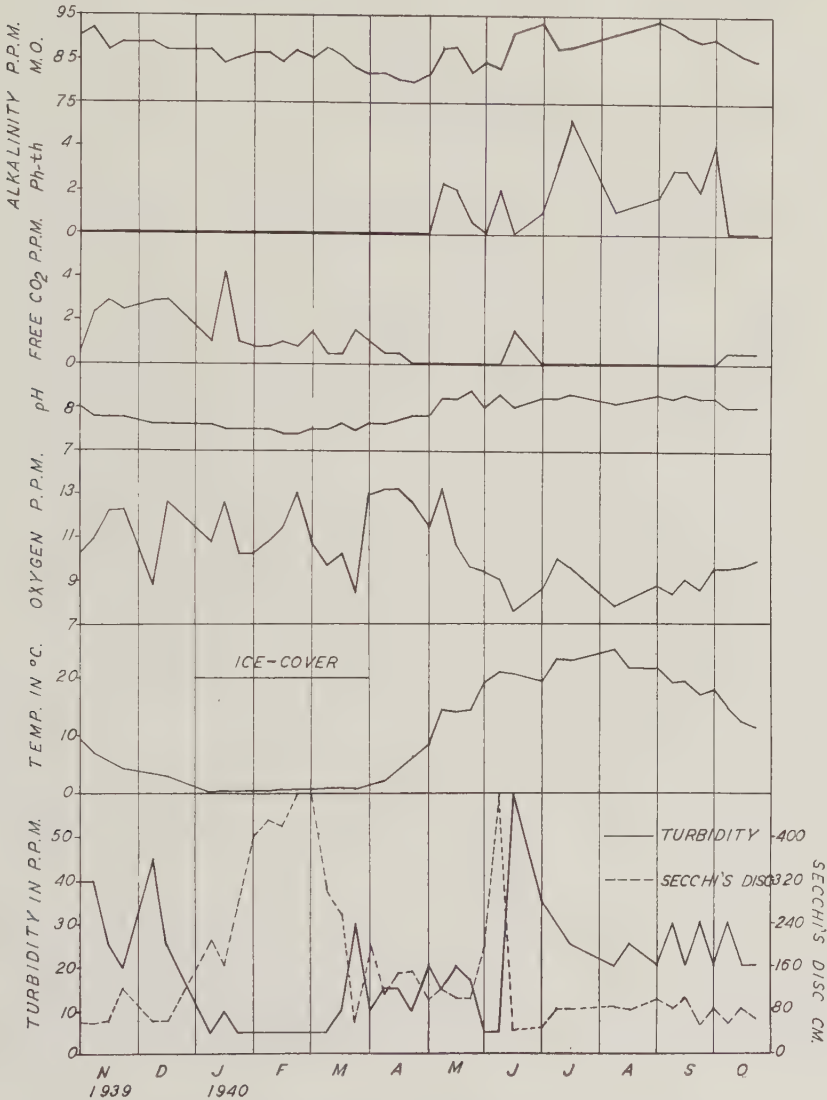


FIG. 1. Values in the upper meter of water for methyl orange alkalinity, ph-th alkalinity, free carbon dioxide, pH, dissolved oxygen, temperature and turbidity. Secchi's disc readings are given in meters.

PHYTOPLANKTON DATA

SEASONAL DISTRIBUTION

Total Phytoplankton

Data concerning seasonal distribution and relative abundance of phytoplankton refer to the standing crop, which was determined by averaging data from collections at surface, 5 m., and 9 m. for a given date. Plankton collections during the present year were made in the same area as those of the preceding year.

Quantitative data pertaining to the standing crop of phytoplankton are shown in Figure 2. Examination of these data shows that in early November, 1939, the quantity was 135,000 units per liter, and following this the quantity decreased gradually until the winter minimum of 7,000 units per liter was reached in January, 1940. Through January and February the quantity was 20,000 units per liter or less, but in early March a sudden increase occurred resulting in 78,000 units per liter by March 21. The following week was characterized by a sudden decrease in abundance of phytoplankton, accompanied by a sudden increase in turbidity. By April the turbidity had decreased considerably and the abundance of phytoplankton had begun to increase; it reached a spring maximum of 374,000 units per liter on May 7. This pulse decreased rapidly until a summer minimum of 8,000 units per liter was attained June 22, at which time high turbidity prevailed. From late June to late August less than 32,000 units per liter were present, but in late August the autumn pulse began and it increased gradually until a maximum of 97,000 units per liter occurred in late September. In October the quantity decreased gradually and by late October only 13,000 units per liter existed. On the whole, the spring pulse of 1940 was distinct and of expected proportions, but the autumn pulse was considerably smaller than the two preceding autumn pulses. This autumn pulse was not only small, but it appeared in two phases, the second part appearing three weeks later than the first. The writer had assembled data for this paper at the termination of the first phase, consequently the second phase has been omitted from this report, except for general data in the discussion.

The following section of this paper gives the salient facts concerning seasonal trends in abundance of the major phytoplankton groups and the predominant genera composing these groups. Species will not be discussed because of the difficulty in recognizing them while making the quantitative counts. A list of phytoplankton species occurring in western Lake Erie, exclusive of diatoms, has been published by Tiffany (1934).

Myxophyceae

Blue-green algae were important constituents of the plankton only during summer and autumn, and in this investigation only 12 genera were encountered in sufficient numbers to be considered important quantitatively. In early November, 1939, blue-greens were present in quantities of 22,000 units per liter, this being the declining portion of a

large pulse with a maximum of 210,000 units per liter that occurred in September and October, 1939. By late November members of this group were nearly absent from the plankton, and they remained at a

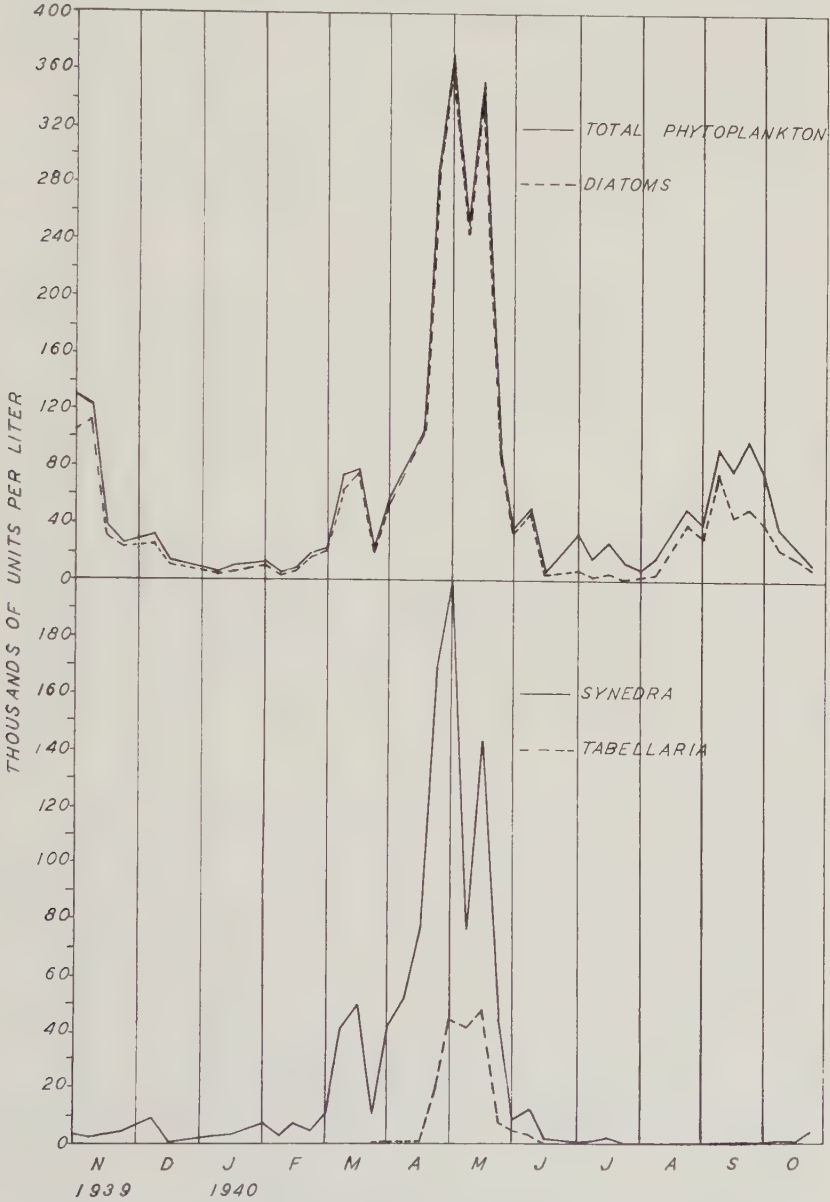


FIG. 2. Standing crop of total phytoplankton, total diatoms, *Synedra*, and *Tabellaria*, in thousands of units per liter.

low level until April, 1940, when they appeared in quantities of 5,000 units per liter (Fig. 3). From March to September blue-greens varied from a maximum of 12,000 units per liter in mid-July to only a few hundred units per liter in June and August. In early September blue-greens increased in abundance and a pulse with a maximum of 40,000 units per liter had occurred by late September. Following this maximum the quantity decreased rapidly until no more than 1,000 units per liter were present by late October, 1940. In general, the periods of maximum abundance of this group occurred at approximately the same times in each of the two years of investigation, but the autumn pulse of 1939 was several times larger than those in 1938 and 1940.

Anabaena occurred from September to mid-October, 1940, in quantities not exceeding 1,500 units per liter.

Aphanizomenon and *Oscillatoria* were combined in making quantitative counts because of the difficulty involved in always distinguishing them under low magnification. These genera were present in all November collections of 1939, but the quantities varied from 18,000 units per liter during the early part of the month to a few hundred units per liter at the end of the month. From December, 1939, to May, 1940, these forms were scarce, but from early May to early June they occurred in quantities of 3,000 units or less per liter. During most of June and July they were present in small quantities, but during August they increased gradually until they reached a maximum of 26,000 units per liter in late September. Following this maximum they declined and by late October the number was reduced to 1,000 units per liter. These genera were most abundant from mid-August to mid-October, but for the three autumns of study considerable variation in quantity occurred. The maxima are as follows: 1938, 8,000 units per liter in September; 1939, 104,000 units per liter in late September; 1940, 26,000 units per liter in late September. Since these two genera constitute a large percentage of the total Myxophyceae these annual variations are of considerable importance.

Aphanocapsa was present in collections from mid-August to mid-September, but the quantity did not exceed 1,000 units per liter.

Aphanothece occurred in collections during July and August, but in quantities of 1,500 units or less per liter.

Chroococcus was absent from collections made from November, 1939, to May, 1940. It reached a maximum of 4,000 units per liter in July, and attained a second peak of abundance of 5,000 units per liter in October.

Coelosphaerium was found in quantities of less than 800 units per liter from November, 1939, to August, 1940. During September and October a pulse appeared with a maximum of 14,000 units per liter and by late October this form had decreased to 700 units per liter.

Gloeotrichia was present in late July and August, but it did not exceed 1,000 units per liter.

Gomphosphaeria occurred only in August and September collections and the quantity did not exceed 1,000 units per liter.

Merismopedia was absent from all collections from November, 1939, to September, 1940, except for one sample in July. A small

pulse occurred during September and October with a maximum of 1,300 units per liter.

Microcystis was absent from the plankton between November, 1939, and July, 1940. It was present in all collections from July to late October, and the maximum abundance of 4,000 units per liter occurred in late August.

Chrysophyceae

Dinobryon occurred from January through May, 1940, but at no time did it exceed 1,300 units per liter.

Mallomonas was present in three collections during May and June, but in amounts less than 1,200 units per liter.

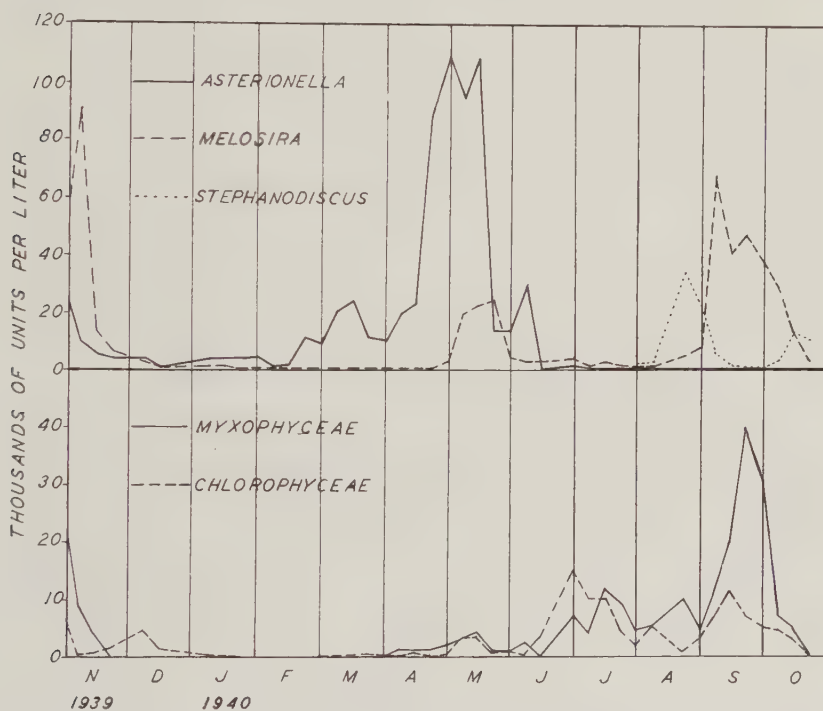


FIG. 3. Standing crop of *Asterionella*, *Melosira*, *Stephanodiscus*, total Myxophyceae, and total Chlorophyceae in thousands of units per liter.

Heterophyceae

Botryococcus was found in several collections during August and September, but never in numbers greater than 2,000 units per liter.

Tribonema occurred during August and September in quantities less than 1,000 units per liter.

Bacillariophyceae

Diatoms were present in all collections and in most instances they

constituted the major portion of each collection. This is borne out by Figure 2 which shows that the curve for seasonal abundance of diatoms resembles very closely the curve for seasonal abundance of total phytoplankton. In early November, 1939, the quantity of diatoms was 106,000 units per liter; this represents the declining part of a pulse with a maximum of 175,000 units per liter that occurred from late August to late October, 1939. Diatoms decreased in quantity through November and December, 1939, and in January, 1940, they reached a winter minimum of 8,000 units per liter. Through January and February, 1940, diatoms did not exceed 20,000 units per liter, but in early March they increased in number, and by mid-March a quantity of 78,000 units per liter was present. This quantity decreased abruptly the following week to 21,000 units per liter, following which the abundance increased gradually, and then more rapidly through April to the spring maximum of 371,000 units per liter in early May. By late May this pulse had begun a rapid decline until in late June less than 10,000 units per liter were present, and the population was further decreased to a summer minimum of 1,400 units per liter in late July. Following this minimum the number of diatoms gradually increased, and produced the autumn pulse which had its maximum of 75,000 units per liter in mid-September. Through late September and early October diatoms decreased in quantity and by November, 1940, only 11,000 units per liter were present. The most conspicuous feature in respect to seasonal abundance of diatoms during this year is the unusually small autumn pulse of 1940.

Amphiprora occurred only in April and May collections, and it did not exceed 1,200 units per liter.

Asterionella was present in all collections except those made in August, September, and October, 1940 (Fig. 3). In early November, 1939, this form was present in quantities of 23,000 units per liter, but it decreased rapidly and remained below 4,000 units per liter from late November, 1939, to mid-February, 1940. It increased in abundance in late February, and continued increasing with certain irregularities to the spring maximum of 108,000 units per liter in early May. The pulse decreased through May and June, and from July to October this form when present did not exceed 700 units per liter. This plankter had one distinct pulse and that occurred in spring, as it did the preceding year. However, in 1939 the spring pulse was larger, and it occurred during February, March, and early April.

Cyclotella occurred in collections of November and December, 1939, with a maximum of 10,000 units per liter, but it was absent in collections made from January to April, 1940. A pulse occurred from mid-April to July, and the maximum of 9,000 units per liter appeared in late May. It was present in collections from late July to November, but it did not exceed 4,000 units per liter.

Cymatopleura was found in collections of November, 1939, September and October, 1940, but it did not exceed 1,500 units per liter.

Cymbella appeared in April and May collections, but it did not exceed 1,200 units per liter.

Diatoma was present occasionally in collections made from November, 1939, to March, 1940, but not in amounts over 1,200 units per liter.

Fragilaria occurred in all collections from November, 1939, to November, 1940, except for the collections of July, August and September. In early November, 1939, the quantity was 4,000 units per liter, but by late November it had decreased to 1,000 units per liter and it maintained this level to mid-April, 1940. A pulse extended from mid-April to June, the maximum being 9,500 units per liter in early May. In October it appeared in quantities not exceeding 1,000 units per liter.

Gomphonema was present in several collections during November, 1939, September and October, 1940, but it did not exceed 1,200 units per liter at any time.

Gyrosigma occurred from November, 1939, to February, 1940; the maximum for the period was 3,500 units per liter.

Melosira occurred in nearly every collection made from November, 1939, to November, 1940, but pulses occurred in autumn and spring (Fig. 3). In early November, 1939, the quantity of this form was 91,000 units per liter; this was the decreasing phase of a large pulse that occurred in late October. From December, 1939, to May, 1940, it was present in numbers less than 1,500 units per liter. A small pulse, with a maximum of 25,000 units per liter, extended from May to early June. From June to September quantities less than 5,000 units per liter were present, but from September to November a pulse occurred with a maximum of 68,000 units per liter.

Navicula was present in most collections, but it did not exceed 1,600 units per liter.

Rhizosolenia occurred from November, 1939, to early February, 1940, in quantities less than 2,300 units per liter. It was absent from collections made from mid-February to mid-June, but from mid-June to early July a small pulse appeared with a maximum of 3,500 units per liter. Due to the fact that this plankter is translucent it is extremely difficult to make accurate counts during periods of high turbidity. Therefore, the abundance of this form may be very different than indicated here.

Stephanodiscus was present in quantities exceeding 700 units per liter only during the autumn of 1940 (Fig. 3). In August and September a pulse occurred with a maximum of 34,000 units per liter, and in October a secondary pulse appeared with a maximum of 13,000 units per liter. This plankter is of particular interest because in the autumn of 1938 it appeared in a large pulse, the maximum being 251,000 units per liter, and it constituted about 95 per cent of the total phytoplankton at this time. Since 1938 it has not appeared in quantities exceeding 34,000 units per liter.

Surirella occurred in collections during November, 1939, in quantities less than 1,000 units per liter, and in May, 1940, a small pulse appeared with a maximum of 4,700 units per liter.

Synedra was present in all collections from November, 1939, to March, 1940, but at no time did it exceed 10,000 units per liter (Fig. 2).

In early March it increased rapidly to 48,000 units per liter, and then dropped to 11,000 units per liter on March 29, at which time turbidity rose suddenly from 5 to 30 ppm. In early April this form began a rapid increase, and it continued to do so until the spring maximum of 202,000 units per liter was reached in early May. Following this maximum the quantity decreased rapidly, and by late July it was scarce. From August to November, 1940, it was absent except for the last collection in October. This plankter, along with *Asterionella*, composed over 90 per cent of the entire spring diatom pulse. The spring pulse of 1939 occurred in February and March, and its maximum was only 48,000 units per liter.

Tabellaria had but one pulse and that occurred from April to mid-June, 1940, the maximum being 47,000 units per liter (Fig. 2). During the rest of the year it was absent or when present it did not exceed 1,200 units per liter.

Chlorophyceae

Green algae composed only a small percentage of the total phytoplankton during this year, and only in summer and autumn were these forms sufficiently abundant to be of quantitative importance (Fig. 3). From early November, 1939, to mid-June, 1940, green algae when present did not exceed 3,000 units per liter, except on two occasions. These exceptions occurred in November and December, 1939, at which time the quantity was 7,000 and 4,500 units per liter respectively. In late June, 1940, this group increased in quantity and formed a small pulse that extended to mid-August; the maximum was 15,000 units per liter. A second pulse, with a maximum of 12,000 units per liter, extended from September to mid-October. In many respects the abundance of green algae in the plankton was very similar for the autumns of 1938 and 1940, but it was more than twice as abundant in the autumn of 1939 than in either of the autumns of 1938 or 1940.

Actinastrum occurred only during September, 1940, in quantities not greater than 1,200 units per liter.

Ankistrodesmus was present in a few collections from mid-April to mid-June, 1940, but it did not exceed 600 units per liter.

Closteriopsis was found in three collections in July, 1940, but it did not exceed 1,200 units per liter.

Closterium was present in four collections in late summer, but the quantity was less than 1,200 units per liter.

Coelastrum was absent from the plankton from November, 1939, to mid-July, 1940. The maximum abundance from July to late October was 1,700 units per liter.

Crucigenia occurred in two collections in September, 1940, and the greatest quantity was 1,200 units per liter.

Dictyosphaerium occurred in collections in November, 1939, with a maximum of 5,600 units per liter. This quantity represented the declining phase of a pulse, with a maximum of 32,000 units per liter that occurred in September and October, 1939. It was absent from December, 1939, to September, 1940, except for a few collections in

July and August, at which time only an occasional individual was encountered. During September and October, a small pulse appeared, reaching a maximum of 6,400 units per liter in late September.

Kirchneriella occurred infrequently in June, July, and August collections, and it did not exceed 700 units per liter.

Oöcystis was absent from collections made from November, 1939, to late June, 1940. From late June to November, 1940, it occurred in most collections, but in numbers less than 1,000 units per liter.

Pediastrum occurred in quantities not exceeding 1,200 units per liter in November, 1939, and it was absent from December, 1939, to June, 1940. It was present in nearly all collections from June to November, 1940, but it was so irregular in quantity that nothing comparable to a pulse appeared. The greatest abundance occurred in early July, and it was 3,300 units per liter.

Quadrigula was present in most collections from late March to early July, and the maximum quantity encountered was 1,200 units per liter in July.

Scenedesmus occurred in most collections in November and December, 1939, but it did not exceed 1,000 units per liter. It was absent from collections from January to May, 1940, but it was present in most collections from May to October. During this latter period it was most abundant in May, June, and July, reaching a maximum of 2,300 units per liter in May.

Schroederia was absent from all collections made from November, 1939, to July, 1940. From July to November it was present in most collections and a distinct pulse occurred from July to September; a maximum of 6,400 units per liter occurred in July.

Selenastrum was found in collections of September, 1940, in quantities less than 1,200 units per liter.

Sorastrum occurred in August and September, 1940, in numbers no greater than 1,500 units per liter.

Staurostrum was present in collections made in July, August, and September, 1940, but it did not exceed 1,500 units per liter.

Westella was found in June, July, and August, 1940, but in quantities less than 1,200 units per liter.

PERCENTAGE COMPOSITION

Composition of the phytoplankton of individual collections, based on percentages that each component group constituted of the total, is shown in Figure 4. The more important facts concerning the composition of this phytoplankton may be summarized by the following statements. (1) Diatoms constituted approximately 85 per cent during November and December, 1939; about 95 per cent from January to late June, 1940; 10 to 33 per cent from late June to mid-August; 80 per cent from mid-August to early September; and 50 to 68 per cent from early September to late October. (2) Blue-greens made up 8 to 15 per cent of the total during November, 1939; less than 5 per cent from December, 1939, to July, 1940; 20 to 60 per cent during July,

August, and most of September and October. (3) Greens composed from 2 to 15 per cent of the total phytoplankton during November and December, 1939; less than 3 per cent from January to late June, 1940; 25 to 60 per cent from late June to mid-August; and 4 to 17 per cent from September to late October. (4) Plankton algae, exclusive of the three groups listed above, designated as miscellaneous in Figure 4, composed less than 5 per cent of any collection made during the period of investigation. Composition of the phytoplankton from September, 1938, to November, 1939, was quite different from that of the period November, 1939, to November, 1940, and these major differences are considered in the discussion of this paper.

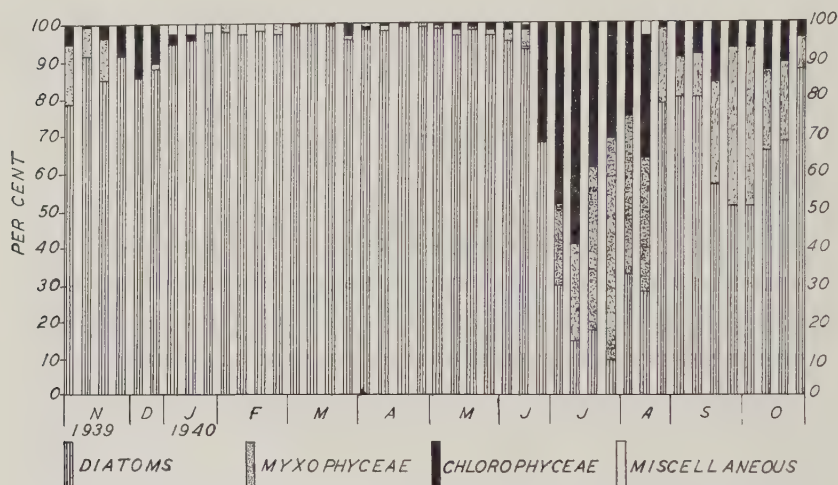


FIG. 4. Per cent composition of phytoplankton for individual collections.

VERTICAL DISTRIBUTION

Quantitative differences in phytoplankton at various depths in western Lake Erie occur, but these differences are so irregular that no one depth has consistently a greater abundance than others. At times the greatest quantity occurs at the surface, while at other times it is most abundant at 5 m., and still at other times it is most abundant at 9 m. Likewise, the qualitative difference of phytoplankton at various depths is so irregular throughout the year that no consistent trend can be discerned. The explanation for this irregularity in the vertical distribution of the quality and quantity of phytoplankton lies in the fact that the shallow water of western Lake Erie is circulated frequently from top to bottom by wind action. It is possible that at times of temporary thermal and chemical stratification the vertical distribution of phytoplankton conforms to a regular pattern; however, thermal stratification in this end of the lake is limited to only a few days each year. Because vertical distribution of phytoplankton is so irregular in this region it has seemed advisable to discuss phytoplankton data in terms of standing crop.

DISCUSSION

The following discussion points out the salient facts concerning the seasonal variation in abundance and composition of the phytoplankton in western Lake Erie, from November, 1939, to November, 1940, and shows how this plankton differs from the plankton of the preceding year. Turbidity is discussed as a factor that may exert considerable influence upon the phytoplankton populations in this area.

In general the physical-chemical factors of the water of western Lake Erie, for the present year (November, 1939, to November, 1940) are very similar to those of the preceding year. However, certain differences exist and these may be summarized. (1) Air temperature from January to April, 1940, was considerably lower than for the same period of the preceding year. During the winter of 1940 the ice-cover was about 16 inches in thickness and it covered the entire western end of the lake, while in 1939 the ice-cover did not exceed 8 inches in thickness and it was confined to the immediate region of the Bass Islands. This difference in extent of ice-cover for the two years had little differential effect on the water temperature. (2) Thermal stratification during both years was limited to a few days in May and June. (3) Turbidity during the winter of 1940 was lower than for the winter of 1939. This difference for the two winters may be explained by the fact that the limited ice-cover of 1939 exposed more water to agitation by wind, while the extensive ice-cover of 1940 protected most of the water of western Lake Erie from wind. (4) Depths to which 1 per cent of the surface light penetrated for the two years bear an inverse relationship to turbidity; consequently, during the seasons of low turbidity light penetrated to greater depths than when turbidity was high. (5) Likewise, Secchi's disc readings for the two years varied inversely with the degree of turbidity. (6) Such factors as dissolved oxygen, pH, alkalinity, and free carbon dioxide differed for corresponding times during the two years, but the writer hesitates at this time to state either the reason for or the importance of these variations.

Phytoplankton pulses occurred in the autumn of 1939, only the latter portion of which is treated in this paper, and in the spring and autumn of 1940. These pulses differed from each other in several respects and from those reported for the preceding year. The declining portion of the autumn pulse of 1939 was composed primarily of *Melosira* and *Asterionella* (Fig. 3), and the period was characterized by turbidities varying from 20 to 40 ppm. The spring pulse of 1940 occurred from mid-March to late May, reaching a maximum of 374,000 units per liter in early May. Diatoms composed 98 per cent of the total phytoplankton and the remaining 2 per cent was divided equally between green and blue-green algae. *Synedra* and *Asterionella* were the dominant forms, but *Tabellaria*, *Fragilaria*, and *Melosira* contributed substantially to the plankton. This pulse began while the ice-cover was still present, but not until the ice-cover had disappeared did the pulse increase rapidly to its maximum. Average turbidity for the three weeks preceding and during the pulse was 15 ppm., a relatively low turbidity for this body of water. Water temperature varied from 0.8° C. to 14.6° C. during the pulse and the maximum abundance of plankton occurred at a temperature of 8.0° C.

TABLE I

Summary data pertaining to phytoplankton pulses in respect to the following: time of occurrence; duration; average, and maximum number of phytoplankters per liter; composition; average turbidity 3 weeks preceding, and during the pulses; and water temperature during the pulses. Each of the two parts of the 1940 autumn pulse has been treated separately, as well as in combined form.

Time of Pulse	Pulse Duration in Weeks	Av. No. Plankters per Liter	Max. No. Plankters per Liter	Av. Turb. During Pulse	Av. Turb. 3 Weeks Preceding Pulse	Water Temp. °C. During Pulse	Percentage Composition		
							Diatoms	Blue-Greens	Greens
Sept. 2-Nov. 5, 1938	9	159,000	330,000	30 ppm.	30 ppm.	23.0-12.0	84	9	6
Feb. 25-April 11, 1939	6	153,000	247,000	42 ppm.	18 ppm.	0.1- 3.2	96	3	1
July 22-Nov. 9, 1939	16	205,000	320,000	23 ppm.	16 ppm.	23.0- 7.4	48	39	12
March 14-May 28, 1940	11	160,900	374,000	15 ppm.	5 ppm.	0.8-14.6	98	1	1
Sept. 13-Nov. 29, 1940 Part 1, Sept. 13-Oct. 4 Part 2, Nov. 9-Nov. 29	8	85,500	111,000	55 ppm.	23 ppm.	19.1- 3.0	77	17	6
	4	85,000	97,000	25 ppm.	22 ppm.	19.1-17.8	60	30	10
	4	86,000	111,000	86 ppm.	25 ppm.	8.3- 3.0	94	4	2

The autumn pulse of 1940 was small, irregular, and extended from September 13 to November 29. It actually occurred as two pulses, the first extending from September 13 to October 4 and the second from November 4 to November 29. These two periods were separated by three weeks, during which time the phytoplankton did not exceed 34,000 units per liter. Table I summarizes certain features of these two pulses combined, but the present discussion pertains primarily to that portion between September 13 and October 4. This pulse extended over a period of 4 weeks and reached a maximum quantity of 97,000 units per liter in late September. Diatoms composed 60 per cent of this plankton, while green and blue-green algae composed 10 and 30 per cent respectively. Predominant diatoms were *Melosira*, *Stephanodiscus*, and *Cyclotella*, all belonging to the order Centrales. Predominant green algae were *Dictyosphaerium*, *Coelastrum*, and *Pediastrum*, while *Aphanizomenon*, *Oscillatoria*, *Microcystis*, *Chroococcus* and *Merismopedia* were the dominant blue-greens. Average turbidity during this pulse was 25 ppm., and the average for the 6 weeks preceding the pulse was 33 ppm. Thus from June until October the water was relatively turbid and the first phase of the autumn plankton pulse was characterized by a short duration, a small number of plankters per liter, the dominance of diatoms, and a comparatively high percentage of greens and blue-greens. This first phase of the autumn pulse is compared with the second phase in Table I.

Comparison of the present phytoplankton data with similar data from other parts of Lake Erie or from others of the Great Lakes offers certain difficulties. Several phytoplankton investigations of Lake Erie and Lake Michigan have been made, but in most instances these studies were either not quantitative or they were limited to 6 months or less. Three noteworthy exceptions to this are the studies of Daily (1938) and of Damann (1940) both on Lake Michigan, and the work of Gottschall and Jennings (1933) on Lake Erie near Erie, Pennsylvania, all three of which were year-round studies. These studies reported: (1) the occurrence of spring and autumn pulses both of which were dominated by diatoms, (2) that the predominate diatoms were *Asterionella*, *Fragilaria*, *Melosira*, *Tabellaria*, *Synedra*, and *Cyclotella*, and (3) that greens and blue-greens were most abundant from June to October. Daily (1938) reported that turbidity fluctuated from week to week due to weather conditions, but it displayed two maxima which were caused by the spring and autumn late turnovers. Each plankton pulse was preceded by increases in turbidity which he interpreted as supporting Pearsall's theory (1923) of diatom periodicity. Damann (1940) who continued the work of Daily on Lake Michigan, found a close parallelism between his own data for 1938-39 and the data for 1937-38 by Daily. One conspicuous difference occurred and that was a greater abundance of *Synedra* during the spring of 1939 than during the spring of 1938. He states, "From evidence now at hand it appears that each genus has high and low productive years which in turn have a pronounced effect upon the total yield of phytoplankton for any one year." Data from western Lake Erie confirm this statement. Gottschall and Jennings (1933), whose study extended over a period of 22

months, found marked differences in size and composition of the two late summer and autumn plankton pulses. Unfortunately no data on turbidity were presented in their report. It appears from the above statements that the composition of phytoplankton pulses of western Lake Erie is quite similar to those reported from eastern Lake Erie and Lake Michigan. However, the pulses differ from each other in respect to time of occurrence and size.

The limnological studies of western Lake Erie by Wright and Tidd (1933), although limited to 6 or 7 months, was conducted in the same general region and the same methods were used as in the present investigation. They reported that the average abundance of phytoplankton groups, in thousands of units per liter, for the period late May to early October, 1929 and 1930, was as follows: diatoms, 90; greens, 38; and blue-greens, 58. For the same period in 1939 the writer's results were: diatoms, 76; greens, 20; and blue-greens, 63. In 1940 they were: diatoms, 30; greens, 6; and blue-greens, 10. These data for 1929, 1930, and 1939 are quite similar, but a marked difference exists between the years 1939 and 1940. Turbidity from late May to early October, 1939, was consistently lower than it was for the same period in 1940. These data support the writer's contention that composition and size of phytoplankton populations in western Lake Erie are affected by the degree of turbidity.

At the termination of the second year of study of phytoplankton and its relation to certain physical-chemical factors in western Lake Erie, certain trends become apparent. It is evident that from year to year the time of occurrence, size, duration and composition of phytoplankton pulses vary considerably. Likewise, physical-chemical environmental factors of the water vary, and some of these variations indicate a direct relationship to phytoplankton trends. Turbidity showed a greater fluctuation than any other factor investigated, and for this reason considerable attention has been given to the variation of turbidity during and immediately preceding the plankton pulses. A study of light penetration and turbidity during the present year (Chandler, 1942) shows that 1 per cent of the surface light may penetrate to a depth of less than 2 m. when turbidity is 60 ppm. or higher, and it may penetrate to depths of 9 m. or more when turbidity does not exceed 5 ppm. It becomes apparent from these data that light penetration is drastically reduced in the waters of western Lake Erie when turbidity is relatively high, all of which suggests that the photosynthetic processes of phytoplankton may at times be limited to the upper few meters of water. Unfortunately, light penetration studies were not made from September, 1938, to September, 1939; consequently, the two years under consideration can not be compared in this respect. However, turbidity was measured both years and a comparison of these data with plankton data is made in Table I.

In an attempt to summarize certain results derived from year-round studies of phytoplankton from September, 1938, to November, 1940, Table I has been constructed. This table includes general data pertaining to time of occurrence, duration, size, and composition of phytoplankton pulses, and data on turbidity and water temperature. These two physical factors have been selected from the numerous factors

investigated because they showed the greatest variation during pulses in these two years. In Table I a plankton pulse has been arbitrarily limited to quantities exceeding 50,000 units per liter. This quantity has been chosen because when it is reached, subsequent to the summer and winter levels, a definite increase in the phytoplankton occurs. The reason for considering turbidity preceding a pulse, in this table, is because the writer believes that conditions antecedent to the time of a pulse may greatly influence the nature of the pulse. The time interval of 3 weeks is an arbitrary selection to which no significance should be attached.

Data in Table I suggest that low turbidity preceding and during an autumn pulse results in a pulse with the following characteristics: (1) long duration, (2) high average quantity of phytoplankton per liter, (3) relatively high maximum, (4) comparatively low percentage of diatoms, (5) comparatively high percentage of greens and blue-greens. These characteristics are representative of the data for the autumn pulse of 1939. Likewise, when turbidity preceding and during an autumn pulse is high that pulse is characterized by: (1) relatively short duration, (2) low average quantity of plankters per liter, (3) may be high or low maximum, (4) high percentage of diatoms, (5) low percentage of greens and blue-greens. These characteristics are representative of the data for the autumn pulses of 1938 and 1940. It appears that high turbidity during or preceding a pulse does not necessarily result in a low maximum for that particular pulse. In the autumn of 1938 turbidity preceding and during the pulse was 30 ppm., yet a high maximum, 330,000 units per liter, occurred. However, 251,000 (more than 75 per cent) of the 330,000 units per liter consisted of *Stephanodiscus*. This genus was abundant for only a short time in the autumn of 1938 and since then it has not appeared in quantities exceeding 34,000 units per liter. It is of interest to note that this quantity of 34,000 units per liter occurred during the autumn of 1940 when turbidity was 30 ppm. Exclusive of *Stephanodiscus* the autumn pulse of 1938 was even smaller than the autumn pulse of 1940. It is possible that during highly turbid conditions only certain diatoms thrive while other plankters barely exist. *Cyclotella*, a form closely related to *Stephanodiscus*, was more abundant in the autumns of 1938 and 1940 than in 1939; this suggests that relatively high turbidity favors its abundance.

If water temperature bears a specific relation to autumn pulses it is not evident from data collected thus far. In general the water temperature cycle in western Lake Erie was about the same for the two years under consideration. Any differences in water temperature during the three autumn pulses were due to differences in time of occurrence and duration of pulses and not due to differences in temperature for corresponding times of different years.

Data pertaining to spring phytoplankton populations (Table I) suggest that low turbidity preceding and during a pulse results in a pulse of long duration with a relatively high maximum. This is illustrated by the spring pulse of 1940. If high turbidity precedes and prevails during a spring pulse the pulse will be of short duration and its maximum will be relatively low. These characteristics are representative of the spring of 1939. It appears that spring pulses are composed

primarily of diatoms regardless of the variations in temperature and turbidity, but the relative abundance of different genera vary from year to year. In the spring of 1939, *Asterionella* was the dominant genus and it reached a maximum of 157,000 units per liter, while *Synedra* ranked second in abundance with a maximum of 48,000 units per liter. In the spring of 1940, *Synedra* was dominant with a maximum of 202,000 units per liter, while *Asterionella* ranked second with a maximum of 108,000 units per liter. Water temperatures were considerably different during the spring pulses of 1939 and 1940, because the two pulses did not occur at corresponding times in the two years. All but the declining portion of the spring pulse of 1939 occurred under an ice-cover, while in 1940 the pulse began under the ice-cover but most of it occurred after the ice had disappeared. It is possible that the differences in turbidity and temperature during these spring pulses may have affected their size, duration and the relative abundance of different genera of diatoms, but it is not clear how these factors are related to the difference in time of occurrence of the two pulses.

A comparison of spring and autumn phytoplankton pulses in western Lake Erie, based on data in Table I, shows the following: (1) duration of spring pulses vary from 6 to 11 weeks, while autumn pulses vary from 8 to 16 weeks; (2) diatoms invariably compose the major portion of the spring pulses, while autumn pulses may be dominated one year by diatoms and the next year by greens and blue-greens; (3) both spring and autumn pulses vary considerably from year to year in respect to time of occurrence.

In the foregoing discussion certain relationships existing between phytoplankton pulses and turbidity in western Lake Erie have been pointed out. Turbidity alone probably has little effect on phytoplankters unless it be through mechanical injury, sedimentation, or the coating of individuals by sediments, and none of these are known to occur in western Lake Erie. The importance of turbidity as a factor influencing phytoplankton populations probably lies in its relation to light penetration. Light studies (Chandler, 1942) in this particular region show that turbidity greatly reduces the intensity of light at various depths, consequently the higher the turbidity the lower the intensity of light at a given depth. Thus it might be expected that this reduction in intensity of light would alter the rate of photosynthesis by phytoplankters at various depths. A recent study by Meyer and Heritage (1941) shows that when water in this region becomes highly turbid the rate of apparent photosynthesis in *Ceratophyllum demersum* is greatly reduced even at depths of 1 m. and less. Their data also show that the compensation point for this species varied from a depth of 10 m. when turbidity was near its summer minimum to a depth of 2 m. when turbidity was near its summer maximum. Unfortunately we do not have comparable data on the depths at which compensation points occur for plankton algae of this region; however, it is likely that the rate of photosynthesis of plankton algae follows the general trends shown by *Ceratophyllum demersum*. If this is true, then highly turbid conditions preceding a phytoplankton pulse might reduce the rate of photosynthesis of algae to such an extent that the quantity of phytoplankton would not reach pulse proportions for some time even though

other conditions favored it. Likewise, high turbidity during a pulse may tend to retard growth and reproduction of algae to such a degree that the pulse will be small and of short duration. If suspended materials in water have a selective effect on light penetration, then certain light rays will be present in greater intensities, at a given depth, than other light rays. If this does occur, then those algae best adapted for the utilization of this selected light will thrive while others will be present in small quantities if not absent. This might be a factor in producing differences in composition of phytoplankton pulses for the same season of different years.

The writer does not believe that the variations of phytoplankton populations from year to year in western Lake Erie can be explained entirely on the basis of light and its relation to photosynthesis, but there is evidence that the reduction of light through the effects of high turbidity may be a limiting factor at times. In arriving at an explanation of the variations of phytoplankton pulses in respect to time of occurrence, duration, size, and composition, the following factors also must be considered: (1) annual and seasonal amounts of solar radiation delivered to the surface of the lake, (2) variation in quality and quantity of dissolved substances in the water, (3) size, function, and activity of the bacterial population, and (4) competition among plankters for food and space. Projects are under way at this laboratory to investigate the first three factors listed.

SUMMARY

1. Year-round limnological data based on weekly observations of phytoplankton and general physical-chemical factors of western Lake Erie are presented.

2. General physical-chemical factors, exclusive of turbidity and ice-cover, were quite similar to those for corresponding times of the preceding year.

3. The ice-cover of 1940 was thicker and it covered a much larger portion of the western end of Lake Erie than it did the preceding year.

4. Turbidity varied from 5 to 60 ppm.; the water was most turbid in summer and autumn, and it was least turbid in winter and spring. In the preceding year turbidity was highest in spring and autumn and lowest in winter and summer.

5. The spring phytoplankton pulse, with a maximum of 374,000 units per liter, occurred from March 14, to May 28, 1940. Diatoms composed about 98 per cent of this pulse and the genera most abundant were *Synedra*, *Asterionella*, *Fragilaria*, *Tabellaria*, and *Melosira*.

6. The autumn pulse occurred in two parts, separated by three weeks. Diatoms composed 77 per cent of this entire pulse and the genera most abundant were *Melosira*, *Stephanodiscus*, and *Cyclotella*.

7. Green and blue-green algae together composed 23 per cent of the entire autumn pulse and about 2 per cent of the spring pulse.

8. Data based on weekly observations indicate that when the average turbidity of the water of western Lake Erie is 25 ppm. or greater preceding and during a phytoplankton pulse, the pulse is small and of short duration. Likewise, when the average turbidity is less than 20 ppm. preceding and during a pulse the pulse is large and of long duration. Diatoms compose a greater percentage of the total phytoplankton when the average turbidity exceeds 25 ppm. than when it is less than 20 ppm. Conversely, green and blue-green algae compose a greater percentage of the total phytoplankton when the average turbidity is less than 20 ppm. than when it is greater than 25 ppm.

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Cellular Biology

Professor Gerard in his book, *Unresting Cells*, has given a popularized treatment of those phases of biology ordinarily included under general or cellular physiology. In addition heredity and gene action, immunity, embryology and the origin of life are discussed. The subject matter is presented in a simple, interesting style which carries the reader, though untrained in biology and chemistry through such detailed topics as protoplasmic structure and enzyme action. Unfortunately, in a few instances the presentation is such that the reader may be led to accept as firmly established explanations which are still open to question.

—K. M. Wilbur.

Unresting Cells, by R. W. Gerard. xv+439 pp. New York, Harper and Brothers, 1940.

STUDIES IN THE BIOLOGY OF THE LEECH.¹

V. BEHAVIOR FOLLOWING NERVE CORD TRANSECTION

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It is axiomatic that the central nervous system plays an essential part in the process of normal locomotion. The sequence of muscle contraction during locomotion has been described for the earthworm (Bovard, 1918). Similar studies have been reported for the leech (Miller, 1936). In this paper a number of reactions are presented which may be considered as traumatic and resulting directly from the complete transection of the ventral nerve cord. A partial explanation of these responses is to be found in the discussion later in this paper.

The procedure involved either the transection of the nerve cord by ventral section or the complete transection of the body. These incisions were made in the anterior, the middle, and the posterior regions. Observations were made over periods of two to twenty days following the operation. The results are recorded below.

ANTERIOR DISSECTION.—1. (Fig. 3).

The ventral nerve cord was cut at the fifteenth annulus. Considering the extent of the cephalization this would place the cut between somite six and seven. It was found that this point of dissection was the anterior limit where recognized differential behavior of both the anterior and posterior portions could be classified. Giant fiber response was unimpaired in the region posterior to the cut. The response to tactile stimulation applied to either end of the posterior section was an end-to-end shortening. When stimulated near the center of the body, especially noted in water, there was an elongation followed by swimming. Tactile stimulation applied anterior to the cut was always followed by a shortening of that region. Crawling movements were expressed independently by both the anterior and posterior portions.

Forward locomotion on a wet slate was accomplished through the extension and subsequent contraction of that portion of the leech posterior to the cut. In this procedure the anterior segments were pushed forward. The random movements of the anterior tip and its subsequent extensions did not produce forward locomotion. Such anterior extensions were not necessarily followed by an extension of the large posterior section. Combined with the usual adherence of the posterior sucker and the extreme disproportionate relation of volume

¹All leeches used in these experiments were *Haemopsis marmoratis* (Say).

between the anterior and posterior sections, it is understandable why forward locomotion by anterior section extension was not accomplished. The fact that this small anterior section was capable of independent forward locomotion was established when it was completely severed from the remainder of the leech.

In shallow water crawling movements did not result in forward locomotion. The failure of the anterior sucker, though functional, to make an adhesive contact following the extension of the posterior section together with the more frictionless substratum, combined to make forward locomotion by this method ineffective. The same limitations apply to the crawling efforts of the anterior section as listed above. Swimming and undulatory movements were not affected by this dissection to the same extent as were crawling movements. In swimming, as in crawling, the anterior end took no active part. Swimming and undulatory movements appeared to be nearly normal with the exception of that portion anterior to the cut. As in crawling, these anterior segments were turned under.

ANTERIOR DISSECTION.—2.

The anterior fifteen annuli were severed from the body. This anterior tip expressed true crawling movements both on the wet slate and in the water. The oral sucker was functional. Actual forward progress was made. Undulatory movements were observed but did not result in forward locomotion.

That portion of the leech minus the six anterior segments remained alive for two days or more. On a moist slate crawling was an effective means of locomotion. In the water, swimming and undulatory movements were common and appeared to be nearly normal. Swimming was the usual response to tactile stimulation.

MID-BODY DISSECTION.—1. (Fig. 2).

The ventral nerve cord was cut in the mid-body region. This cut divides the central nervous system into two nearly equal portions. It was then possible to observe certain expressions of behavior not clearly evident in the preceding experiment. Under this condition the leech moved forward by crawling as well as swimming.

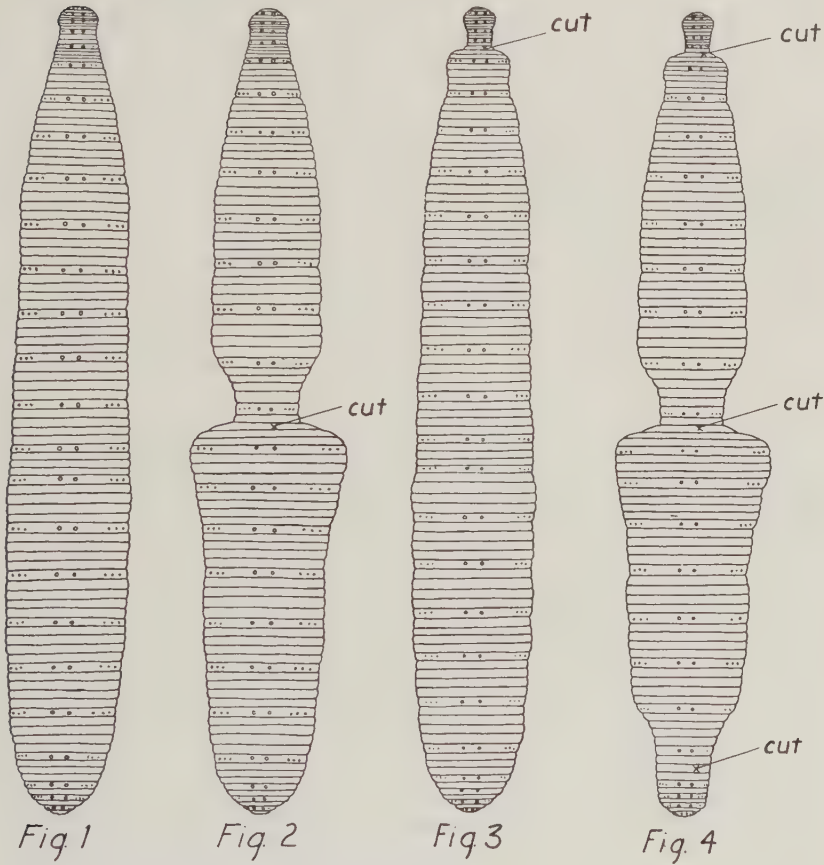
In crawling on the wet slate there were two alternatives. (1) Normal crawling movements of the anterior half up to the cut and the dragging of the posterior half. (2) Crawling movements originating posterior to the cut and proceeding in such a way that the anterior half was pushed ahead. Both methods were observed for the same animal, although they did not take place simultaneously.

In the water, crawling movements were observed only in that portion anterior to the cut. Frequently both suckers were attached following the forward extension of the anterior half. Forward movement occurred only after much twisting and pulling and finally the slipping of the posterior sucker over the substratum. It would appear that the posterior half was moved forward solely by the force of the contraction of the longitudinal muscles in that portion anterior to the

cut. When the posterior sucker became unattached and the animal was engaged in crawling, the posterior half was dragged along.

Swimming movements and undulatory (breathing) movements were expressed either simultaneously or separately by both body sections. It is probable that each section acted independently. Crawling movement of the anterior section was frequently observed to take place

Haemopsis marmoratis (Say)



simultaneously with the swimming movement of the posterior section. Swimming movements of the posterior half alone often resulted in forward locomotion. The anterior half, in such instances, was inactive and folded back along the body. Other post-operative responses of an abnormal nature included the attachment of the anterior sucker at a time when the posterior half was engaged in undulatory movements.

Random movements were confined to that portion anterior to the cut. Tactile stimulation applied anterior to the cut usually resulted

in a shortening followed by crawling movements of this region; similar stimulation applied posterior to the cut usually resulted in an extension followed by swimming movements of that region.

MID-BODY DISSECTION.—2.

The body of the leech was cut into two nearly equal parts both of which exhibited crawling and swimming movements. The anterior portion was more efficient in crawling, the posterior portion in swimming. Random movements were confined to the anterior section. The same responses to tactile stimulation were observed as stated previously under conditions of nerve cord transection only.

POSTERIOR DISSECTION.

The nerve cord was cut just anterior to the anal opening. Crawling movements were normal anterior to the cut. The attachment of the posterior sucker often delayed forward locomotion. The same pulling and slipping was observed as in previous experiments. Normal end-to-end contraction followed tactile stimulation anteriorly.

Swimming and undulatory movements under conditions just described presented a paradoxical procedure. In these instances a most unusual response was observed. Never before have backward swimming movements been observed in leeches by the author. Following the posterior cut in the nerve cord, the leech was dropped into a large crystallization dish containing an inch and a half of water. Swimming movements were initiated upon contact with the water. The leech swam a short distance backward, then while still undulating reversed its direction and swam forward. First one end and then the other took the lead in the initiation of the whip-like movements. For some time following the above dissection forward locomotion by swimming was ineffective. Later observations disclosed more frequent and successful forward movements. Normal undulatory movements were observed when the posterior sucker was attached. There were many instances, however, during this experiment when the anterior sucker became attached and the undulatory movements proceeded (contrary to normal) from posterior to anterior end. Throughout this experiment the leech remained abnormally extended.

ANTERIOR-POSTERIOR DISSECTION.—1. (Fig. 4, without mid-body cut in cord).

The ventral nerve cord was cut near the anterior end and near the posterior end. Crawling of the middle section was observed on the slate. The anterior tip was pushed forward and the posterior segments dragged. Each sucker retained its power of attachment. In the water this animal was much more active than on the slate.

Swimming activity following anterior-posterior cord transection was abnormal. Both anterior and posterior ends moved up and down simultaneously. The leech was abnormally elongated and progress was slow. The anterior end was usually foremost in locomotion. Undulatory movements continued with the whip-like action being initiated at either the anterior or posterior end. When the anterior

end was attached, undulatory movements proceeded abnormally from the posterior to the anterior end. When the posterior end was attached, the whip-like movement proceeded from anterior to posterior as in the normal sequence. Undulatory movements were also observed when both anterior and posterior suckers were attached. The wave of undulation proceeded posteriorly. This anterior-posterior sucker attachment suggests that the middle portion only was involved in the undulation.

ANTERIOR-POSTERIOR DISSECTION.—2.

The anterior end and the posterior end were severed from the body. On the slate the middle section of the leech initiated normal crawling movements and some progress was made. In the water swimming and crawling movements were both exhibited. Swimming movements resulted in moderate progress.

At this point several additional segments were removed from both the anterior and the posterior ends. This additional reduction in the main body of the leech did not alter the basic reactions. Crawling and swimming were continued with proportionately less efficiency. This procedure was repeated with similar results until the remaining piece consisted of but a few segments. It was noted that each section thus removed also expressed movement essentially comparable to crawling or swimming.

DISCUSSION

In preceding papers of this series (Miller, 1933-36) the functional anatomy of the nervous and muscular systems, as well as certain normal responses of the leech have been described. The transection of the ventral nerve cord was noted as especially affecting the following activities.

Random movements are orientation activities. Such movements consist of a succession of extensions and contractions of the anterior end. Following nerve cord transection all random movements were confined to that region anterior to the cut.

Looping movements are modifications of crawling activity. Following the normal elongation of the animal the ventral longitudinal muscles contract in such a way that the animal forms a loop. In this arched position the anal sucker is attached just posterior to the oral sucker. Looping movements were not observed at any time after the ventral nerve cord was cut. Assuming that looping movements involve an anterior-posterior coordination, the cessation of this activity following nerve cord transection is understandable.

Crawling movements or movements of reptation as they are frequently called, are the result of coordinated contractions of body wall muscles. In forward locomotion a wave of circular muscle contraction proceeding from anterior to posterior is followed by a wave of longitudinal muscle contraction. Circular muscle contraction results in the elongation of the animal and the subsequent forward movement of the anterior end. During this phase of locomotion the posterior sucker normally remains attached. The anterior sucker becomes attached at the conclusion of

the forward extension. The release of the posterior sucker and the contraction of the longitudinal muscles are followed by a shortening of the animal.

The cutting of the ventral nerve cord or the complete transection of the body were factors incident to modifications in crawling activity. As was pointed out in the main body of this paper, crawling movements were expressed independently by either the section anterior or the section posterior to the cut. Antagonistic action was often observed between the two sections. This was indicative not only of complete nerve separation, but of certain inherent behavior within isolated sections. Friedlander (1894) and Biederman (1904) in their discussion of locomotion in the earthworm emphasized the "pull" exerted by the elongating portion of the animal as a cause of successive contractions. It was suggested for the earthworm that this pull or stretch initiated impulses which were responsible for continued crawling movements throughout the length of the worm. This is not true for the leech. The observations and discussion presented under mid-body dissection, 1, in this paper is the basis for this statement.

Swimming and undulatory movements are essentially the same. The waving movements which occur while the leech is posteriorly attached to the substratum are referred to as undulatory or breathing in character. The same movements while the leech is unattached result in locomotion and are defined as swimming movements. The rhythmic wave of alternate contraction of the dorsal and ventral longitudinal muscles are responsible for this activity. The ventral longitudinal muscle area is larger and therefore probably capable of exerting greater force than the dorsal area. From observation it appears that the power stroke in this movement is largely produced by the ventral series. During undulatory or swimming activity the animal is extended and dorso-ventrally flattened. The latter is probably the result of the contraction of the dorso-ventral muscle fibers.

In swimming as in crawling the separate sections express independent action. In the various experiments the anterior half was observed in crawling at the same time that the posterior half was engaged in undulation. A previous study (Miller, 1934) has established a difference in rate between normal undulations while attached as compared with number (per min.) of undulations while swimming. The application of this information makes possible the present differentiation between swimming and undulatory (breathing) movements. On this basis it can be stated that operated animals expressed swimming movements while the posterior sucker remained attached. This activity was particularly evident following posterior cord transection. In this instance only the portion anterior to the cut was engaged in swimming activity, while that portion posterior to the cut, including the anal sucker, acted independently.

Swimming and undulatory movements were expressed by groups of segments cut from any body region. This indicates that this activity is not dependent upon any particular area such as anterior, middle, or posterior regions of the central nervous system. Transection of the nerve cord in the posterior region did, however, temporarily inhibit

normal swimming. A temporary reversal in the direction of the undulatory wave produced backward swimming movements.

Deviations in behavior and body form not previously discussed are as follows. When the nerve cord is cut near the anterior end or in the mid-body region the portion of the leech anterior to the cut may fold back along the ventral surface. This was most frequently observed during crawling and swimming when the cut was made in the anterior region, and during swimming when the cut was made in the mid-body region.

This conspicuous ventral folding just anterior to the cut followed complete relaxation of the longitudinal muscles in that area. It has been established experimentally (Miller, 1936) that the motor neurons innervating the longitudinal muscles extend from posterior to anterior in the cord. The immediate contraction of the ventral longitudinal muscles anterior to the cut may be attributed to direct stimulation through sub-epidermal nerve innervation. During crawling or swimming activity in which that portion anterior to the cut is taking no part the animal literally bends in that region in which the longitudinal muscles are relaxed. The bend follows the line of least resistance. After the cutting of the cord, the following change in body shape was noted. The operated leech showed in the region of the cut (except near the posterior end, see Fig. 4), a conspicuous constriction extending anteriorly, and an equally obvious enlargement extending posteriorly. In the mid-body region a typical segment consists of five annuli. In the segment anterior to the cut, there was a loss of tone in the longitudinal muscles. Posterior to the cut there was a corresponding loss of tone in the circular muscles. The area thus affected, depending upon the relation of the cut to the segmental ganglia, extended from three to five annuli anteriorly and from four to six annuli posteriorly, Fig. 2.

These observations further substantiates previous experimental data relative to the position in the ventral nerve cord of the motor fibers innervating body wall muscles. It further suggests that certain motor fibers extend for only a short distance in the cord. As determined from these observations it would appear that the motor nerve cell bodies, the extensions of which innervate the circular muscles, are located in the ganglion anterior to the segment containing the muscles innervated. Further, that the motor nerve cell bodies, the extensions of which innervate longitudinal muscles, are located in the ganglion posterior to the segment containing the muscles innervated.

CONCLUSIONS

1. Abnormal behavior follows the complete transection of the ventral nerve cord.
2. Types of behavior known to be affected include crawling, looping, swimming, and undulatory movements.
3. A given region of the animal may respond normally, while in another section cessation or a reversal from normal behavior is observed.

4. Following the cutting of the ventral nerve cord, there is a loss of tone in the circular muscles immediately posterior to the cut.

5. Following the cutting of the ventral nerve cord, there is a loss of tone in the longitudinal muscles immediately anterior to the cut.

6. Swimming and undulatory movements may be carried on by either the anterior, the posterior, or middle section of the leech's body.

7. The cutting of the cord does not affect the functional capacity of either the anterior or posterior sucker.

8. Looping movements are not observed after a cut in the cord is made.

9. Giant fiber, or end-to-end, reaction is retained in sections just anterior or posterior to the cut.

10. Tactile stimulation produces an end-to-end contraction in the region anterior to the cut.

11. Random movements are confined to that portion of the animal anterior to the cut in the cord.

12. Backward swimming movement sometimes follows the cutting of the cord near the posterior end.

13. Undulatory movements originating posteriorly are expressed following the cutting of the cord near the posterior end.

14. An intact ventral nerve trunk is a necessary prerequisite to normal co-ordinated crawling, looping, swimming, and undulatory activity.

15. Certain motor fibers extend for only a short distance in the cord.

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